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All communications should be addressed to the Editor.

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Notices of the Royal Aëronautical Society.

Chairman-Elect.

At a meeting of the Council held on June 28th, Professor Leonard Bairstow, C.B.E., F.R.S., Fellow, was elected Chairman for the year 1922-1923. Professor Bairstow will assume office on October 1st next.

Examination.

The first Associate Fellowship examination, in accordance with the new regulations, will be held on Monday, September 25th (Part I.), and Tuesday, September 26th (Part II.), in the Library, at 7, Albemarle Street, London, W.1. Entries, accompanied by the prescribed examination fee, should reach the Secretary not later than Monday, August 28th.

Funds.

Full lists of subscribers to date of the R.38 Memorial Research Fund, Usborne Memorial Fund, and Pilcher Memorial Prize for Students are printed in this issue.

It has been decided to utilise the R.38 Memorial Research Fund as follows:—

(*a*) To the placing of a memorial tablet in the Society's offices.

(*b*) To the awarding of an annual prize of 25 guineas for the best technical paper on aeronautics, preference being given to those dealing with an airship subject. This prize to be open to international competition.

(*c*) To the selection and collation of information on the development of design of airships to the present stage.

The balance of the income being allowed to accumulate at present.

The interest of the Usborne Memorial Fund is to be devoted to the award of a prize in every alternate year (unless the amount be such as to allow of an annual prize to the value of £10) for a historical paper on any aspect of aeronautics. This prize will also be open to international competition.

Detailed regulations for these two prizes are being drawn up.

The conditions of award of the Pilcher Memorial Prize for students have already been announced.

Office Closing.

The Offices of the Society will be closed from July 31st to August 14th inclusive.

W. LOCKWOOD MARSH, *Secretary.*

R.38 MEMORIAL RESEARCH FUND.

Donations Received to Date.

	£	s.	d.
H.R.H. The Prince of Wales, K.G.	10	0	0
H.R.H. The Duke of York	5	0	0
Sir Alan Anderson ...	105	0	0
W. H. Coates, Esq. ...	105	0	0
Lord Invernairn	105	0	0
Rt. Hon. Lord Weir ...	105	0	0
Messrs. Vickers, Ltd. ...	105	0	0
Lloyd's Royal Exchange...	100	0	0
Council of Royal Aëronautical Society... ...	63	15	0
Viscount Cowdray ...	52	10	0
12th Squadron, Royal Air Force, Germany ...	43	7	3
Proprietors of "Daily Telegraph"	25	0	0
An American Sympathiser	25	0	0
Lady Shelley-Rolls ...	25	0	0
Sir John Hunter	20	0	0
Flight Lieut. A. H. Wann	20	0	0
Sir A. Denny, Bart. ...	15	15	0
Mrs. E. M. Hilder ...	10	10	0
H. P. Marsh, Esq. ...	10	10	0
Sir H. McGowan	10	10	0
Staff of Royal Airship Works, Cardington ...	10	10	0
G. Holt-Thomas, Esq. ...	10	10	0
Sir J. Maclay	10	10	0
Lord Glentanar	10	0	0
V. Stefansson, Esq. ...	10	0	0
Griffith Brewer, Esq. ...	10	0	0
Lord Foley	10	0	0
Lt.-Col. J. Dunville ...	10	0	0
H. E. Yarrow, Esq. ...	10	0	0
Lt.-Col. W. Lockwood Marsh	10	0	0
Mrs. Waterlow	10	0	0
2nd Squadron, Royal Air Force, Fermoy	9	0	0
47th Squadron, Royal Air Force, Helwan, Egypt...	7	11	7
"From the wreck" ...	6	10	0
Staff of U.S. Military Attaché	6	0	0
Lord Gorell	5	5	0
J. E. Hodgson, Esq. ...	5	5	0
R. P. Wilson, Esq. ...	5	5	0
Mr. and Mrs. W. J. Anderson	5	0	0
Sir Mortimer Singer ...	5	0	0
Flight Lieut. A. S. Booth	5	0	0
70th Squadron, Royal Air Force	4	17	0
Staff of U.S. Naval Attaché	4	10	0
Mrs. W. Lockwood Marsh	3	10	0
Lord Montagu of Beaulieu	3	3	0
Major-Gen. Sir W. Sefton Brancker	3	3	0
Major C. C. Turner ...	3	3	0
Anon	3	0	0
Major G. H. Abell... ...	2	12	6
Flight Lieut. F. M. Rope	2	2	0
H. B. Wyn-Evans, Esq. ...	2	2	0
A. H. Ashbolt, Esq. ...	2	2	0
A. P. Cole, Esq.	2	2	0
Mrs. N. G. H. Hodgson...	2	2	0
G. Reid, Esq.	2	2	0
S. Payne, Esq.	2	2	0
A. E. L. Chorlton, Esq....	2	2	0
Squadron Ldr. D. Harries	2	2	0
Major-Gen. W. Gwatkin, Canadian Air Force ...	2	2	0
H. B. Pratt, Esq.... ...	2	2	0
F. J. McConnell, Esq. ...	2	2	0
Anon	2	0	0
Flying Officer J. S. G. Wrathall	1	10	0
Capt. Basil Miller	1	1	0
Flight Lieut. H. C. Irwin	1	1	0
Rev. Basil Phillips ...	1	1	0
E. H. Lewitt, Esq. ...	1	1	0
Major C. F. Abell ...	1	1	0
Col. Ivan Davson	1	1	0
Major B. F. S. Baden-Powell	1	1	0
John Newton, Esq. ...	1	1	0
Comr. H. T. A. Bosanquet	1	1	0
Sir Charles Bright ...	1	1	0
"B.C."	1	1	0
E. R. Calthrop, Esq. ...	1	1	0
Miss B. Haigh	1	1	0
Sir Samuel Roberts ...	1	1	0
Flight Lieut. J. Barron ...	1	0	0
S. E. Taylor, Esq. ...	1	0	0
S. H. Phillips, Esq. ...	0	10	9
A. E. Marsland, Esq. ...	0	10	6
"J.T."	0	10	0
Capt. A. E. Heatley ...	0	10	0
Capt. J. B. Walker ...	0	5	0
Total	1208	16	7
Interest on deposit up to 31st Dec., 1921 ...	2	6	1
Total	£1211	2	8

PILCHER MEMORIAL PRIZE FOR STUDENTS FUND.

Donations Received.

	£	s.	d.		£	s.	d.
Sir Trevor Dawson ...	26	5	0	Sir Alfred Yarrow ...	10	10	0
F. W. Lanchester, Esq. ...	25	0	0	Sir J. C. Calder	10	0	0
The Pilcher Family (per Mrs. Tidswell)	25	0	0		£137	5	0
Walter G. Wilson, Esq....	25	0	0				
Lord Weir	10	10	0				

USBORNE MEMORIAL FUND.

Donations Received.

	£	s.	d.		£	s.	d.
G. Holt-Thomas, Esq. ...	25	0	0	Capt. G. Usborne ...	2	2	0
David Hawes, Esq. ...	10	10	0	Capt. C. V. Usborne ...	2	0	0
J. H. Mandleberg, Esq. ...	5	5	0	Air Cmdre. O. Swann ...	1	1	0
Wing Comr. T. R. Cave-Browne-Cave	5	5	0	Sir R. Threlfall	1	1	0
Air Cmdre. E. A. D. Masterman	5	0	0	T. A. Monckton, Esq. ...	1	0	0
Lord Rayleigh	3	3	0		£63	9	0
The late Air Cmdre. E. M. Maitland	2	2	0				

PROCEEDINGS.

ELEVENTH MEETING, 57th SESSION.

A meeting of the Royal Aeronautical Society was held at the Royal Society of Arts, Adelphi, London, on Thursday, March 30th, the Chairman, Lieut.-Col. M. O'Gorman, in the chair.

The CHAIRMAN called upon Captain G. De Havilland to read his paper on "The Design of a Commercial Aeroplane."

THE DESIGN OF A COMMERCIAL AEROPLANE.

In order to keep within reasonable limits of a vast subject, I propose to discuss a typical commercial machine and to attempt to give some of the reasons which govern the choice of this particular type.

I hope these views on design will be freely criticised by those interested in transport services and thus bring about an exchange of ideas which must be of value to both operators and designers.

The object of aerial transport is the carrying of passengers and goods by air from one point to another in the shortest possible time consistent with:—

Safety,
Comfort,
Economy.

At the present time the type of machine is largely decided by the type of engine available, and as there are no very high powered engines suitable for commercial work, a large machine will necessarily be a multi-engine one.

The problem firstly resolves itself into what to do with a given engine:—

(1) To build a multi-engine machine, or
(2) A single-engine machine.

A multi-engine machine has generally been found in practice to cost more for construction than two single-engine machines using similar engines.

Among the reasons for this higher cost are the necessity for specially large sheds, the greater difficulty of handling larger units during construction, complication of engine controls and other reasons.

The large multi-engine machine also suffers from definite disadvantages from the service point of view, one of the most serious being that it must be more often out of commission owing to engine breakdown or adjustment, and being a large machine involves a greater financial loss while under repairs. Larger running sheds are necessary and the cost of handling on the ground and of salvage in the case of breakdown is relatively high.

Unless a twin-engine machine is much over-engined—and therefore uneconomical—it cannot fly on one engine with anything like full load. Therefore, if it has normal engine power and one engine cuts out it will be in nearly as bad a case as the failure of a single-engine machine, for the reason that although it can prolong the glide on one engine, it is not under good control owing to the side pull of the engine. It would seem, therefore, that under these conditions any supposed gain is at least open to doubt.

But if a machine carries two engines it must be nearly twice as likely to suffer from engine failure compared with a single-engined machine, therefore a twin machine must be more liable to forced landings.

The primary object of a twin-engine machine should be its ability to fly on one engine and therefore its comparative safety from forced landings. In this case the line of development would seem to be less weight per h.p. and a better arrangement of engine positions and improvement in control gear. The machine would then be easy to fly on one engine as regards control, and would at least give a very flat glide and allow the choice of a much greater area for landing.

It is very doubtful whether a machine of this type could be run economically at the present time, even allowing for a generous subsidy.

Although it is possible to make out a comparatively bad case against the twin or multi-engine machine, there are other conditions than purely economical and constructional which may govern the future development of the type. Public opinion may favour the multi-engine type although there is little or no reason at present why it should do so.

The only figures I have been able to obtain in connection with the relative reliability of twin and single-engine machines on the London-Paris service show that about 200,000 miles were covered by both types in a certain period and two forced landings occurred to both types involving some damage to the machines, but no injury to passengers.

There is little doubt, however, that the multi-engine machine will continue to develop together with the single-engine type.

If we assume the single-engine machine to be the more immediately suitable type, the problem then resolves itself into whether to build a large slow machine or a small fast one.

This brings us to the vital factor of wing loading, which requires very careful examination. *A relatively heavily loaded machine is fast, of low first cost, and economical to run and maintain.* It is therefore a desirable machine in every way, provided the higher landing speed can be safely dealt with and the "get off" is satisfactory. The relatively high landing speed can be dealt with in a satisfactory manner. The chief disadvantage to high landing speed has been the long run after touching, but this can be easily reduced to a reasonable figure by providing for a large ground angle so that the planes act as a very considerable air brake. Any reasonable landing shock can be dealt with by a good shock-absorbing undercarriage.

As an example, a test at Martlesham on a machine which has a ground angle of about 17° and a loading of 11.3 lbs. sq. ft. (R.A.F. 15 section) gave a pull up of 163 yds. in a five-mile wind. This type of machine has flown about 1,200 hours on service and there has never been a mishap which could have been avoided had the landing speed been slower. This is after all the best proof that the landing difficulties are practically no greater than in the case of a lightly loaded machine. Experience with wheel brakes has not given very good results. I witnessed a case of a large machine landing with wheel brakes in action. The pilot landed on a soft wet aerodrome and taxied over one hundred yards with the wheels locked, and it was found that the machine taxied almost as easily as with the wheels free. Some form of non-skid tyre might improve matters, but probably very little on a soft aerodrome. Wheels would certainly have to be made stronger and probably heavier to deal with the high stresses incurred by "breaking."

The large ground angle method of pulling up means a greater skid load, but this can be easily dealt with without incurring much extra weight.

The various methods which have been suggested for increasing lift and obtaining slower landing speeds have not yet been sufficiently developed to warrant a definite statement as to their practical value.

What is required to estimate this value is an answer in terms of a completed serviceable aeroplane to the following question:—"For a given 'get off' and

quantity of load, what increase of speed is possible over that obtained by existing methods?"

If one tries to visualise aeroplanes obtaining their lift from surfaces having much smaller dimensions than those used in modern aeroplanes, it is obvious that new difficulties will crop up, particularly in the matter of control. These difficulties might in many cases be insurmountable, or might be surmounted at too great a sacrifice when considered in the light of the question just asked.

It is necessary to specify a "get off" that will be safe under all reasonable working conditions, and this is probably best done by specifying a given height to be cleared in a given distance. We have made numerous full-scale tests with a view to finding out what constitutes a safe "get off" and to get a reliable method based on trials for predicting the "get off" of any type of machine. From these trials, and experience of actual service conditions, the limiting "get off" for fully loaded machines was that a height of 50 ft. should be reached in 450 yards from a standing start in a calm. This seems to be satisfactory in practice. These conditions can be fulfilled by a machine having a light loading and comparatively high weight, but this type has other disadvantages.

Taking a similar engine in each case, the lightly loaded machine is larger and therefore more costly. Shed space, handling, insurance, maintenance and depreciation are all more. Petrol and oil per mile flown are more, and larger tanks must be carried. The percentage loss of ground speed in adverse winds is greater owing to slower speed.

Against these disadvantages must be set the greater carrying capacity of the lightly loaded machine (if designed for the same "get off").

All these factors when balanced out against each other for 1,000 hours flying indicate that the passenger mileage is a maximum for a machine having a stalling speed of about 55 m.p.h., while owing to those costs which depend on the first cost of the aeroplane, the "all in" cost per seat per London-Paris trip reaches a minimum for stalling speeds between 58 and 62 m.p.h.

The machines with higher stalling speeds have, of course, the very great advantage of high cruising speed. There is in addition the fact that high speed will frequently permit of a whole extra trip being made in the day instead of just extra mileage as assumed above.

From the above reasoning it would seem that the best compromise at the present time is a comparatively small single-engine machine of fairly high wing loading. This machine, with an engine of 450 h.p., will carry about 2,000 lbs. of freight at a cruising speed of over 100 m.p.h., with a range of 350 miles. Whether this machine should be a monoplane or a multiplane is still an open question and actual full-scale tests only can decide the merits of each type.

We had looked into the monoplane type at various times theoretically and it seemed to offer only a moderate advantage over the biplane with most wing sections.

It seemed, however, that if the aerodynamic qualities were exactly the same as a corresponding biplane, the monoplane construction would be worth while owing to the smaller surface required and general fewness of parts making for a robust construction. In the preliminary lay-out it was found by integrating the forces on the various sections of the wing that a lift coefficient of about .7 would be obtainable. Later on, wind channel tests showed a distinctly better figure on the tapered wing used, and tests on the complete model demonstrated that the presence of the fuselage increased the lift so considerably as to bring the lift coefficient up to .86.

An estimate of the weight of wing structure showed that it was safe to expect the weight of the monoplane wing to be at any rate no more than the equivalent R.A.F. 15 biplane wing structure with an increase of speed range of about

10 m.p.h. The actual aeroplane has borne out these figures, as the weight of the wing structure is 1,050 lbs. and is equivalent to a R.A.F. 15 biplane structure of 740 sq. ft. loaded to 10¼ lbs.

It has not as yet been possible to get official performance figures, but from the tests carried out at the works, it is evident that there is a general agreement with the wind channel results. The loading with full load will be 17 lbs. sq. ft., most flights have been carried out at 15 lbs. sq. ft., and with this loading the machine lands at about 54 m.p.h. A speed trial at 10,000 ft. with this loading gave 116 m.p.h. Accurate tests are needed to confirm these figures, but it seems evident that the results expected from this wing construction are realised as near as possible and that this big jump in lift coefficient and consequent reduction of area can be translated from model to full scale without serious error.

This aeroplane has shown some interesting and difficult features. It was anticipated that the propeller problem would be a difficult one with existing gear ratios. This has been verified in practice and the need for lower propeller speeds is manifest. Small variations of the disposition of obstructions in the slipstream have a remarkable effect on the performance. The controls also have presented unusual features. The lateral control is very good, but rudder and elevator control are soft, while rudder control when taxi-ing is entirely absent.

The stability of this type tends to be more marked than the ordinary machines. Among the reasons for this are, doubtless, the facts that it has a larger range of angles of incidence and a smaller downwash than might be expected at slow speeds. Both these factors would tend towards fore and aft stability. Another practical point to be reckoned with is that in a commercial machine the space taken up by the spars in the cabin is rather large, and also the fact that spare wings are not so easily transported as is the case with a biplane. There is no doubt that every considerable increase of lift coefficient will produce difficulties which take some time to surmount. It is now obvious that the cantilever monoplane has very great promise, and it remains to work out the incidental difficulties in order to transform the promise into practical performance.

Construction.

It is difficult to find any advantages in metal construction at the present time for normal climates. The idea that it is safer than wood is not warranted by the evidence available. Metal construction is considerably higher in cost and it is liable to be heavier than wood unless excessive cost is incurred in construction, and it is probably less durable than wood when very thin metal and numerous rivets are used. This is partly owing to the difficulty of effectively protecting thin metal from corrosion. It will, of course, find its place in the future, but at the present cost alone puts it out of court. In tropical climates and climates having extreme variation, metal construction may be immediately necessary and the extra cost will then be worth while. Further data is necessary as to what actually happens to wooden machines.

The cost of commercial machines must be as low as possible, and this calls for the simplest possible construction. It can generally be assumed that the smaller the number of parts in any structure, the cheaper and safer it will be, and for these reasons a plywood covered structure is to be recommended. Plywood has the advantage of forming a substantial covering in place of fabric and at the same time lends itself to the construction of watertight bodies. A three-ply fuselage will stand a great amount of damage before collapse occurs, certainly more than a wire-braced structure. As a skin for both covering and bracing it is far preferable to sheet metal which, owing to its relative thinness, is very liable to dent and crack and is difficult to protect from corrosion.

Metal struts in fuselage or wing structure do not generally offer advantages over wooden members when considering simple and economical construction.

Wing spars are in a similar case, as it is at present impossible to standardise sizes of spars and thus make use of special metal sections.

There seems little doubt that wood construction will continue to hold its own for a considerable time in places where climatic conditions are fairly normal.

Rather than work on a very high factor of safety for the vital members of the structure and incur extra weight, it would seem preferable to allow for duplication of the stress path wherever possible. This does not always mean providing two similar members side by side, but rather by so arranging members that in the case of breakage of a part the stress is distributed in a possibly different manner and with a reduced factor of safety.

However strong a member is made there will always be a chance of failure through flaw or careless assembling. It might be a strained bracing rod with an internal flaw or the omission of a cotter pin in a vital place. In either of these cases complete failure of the structure might result if there was no form of duplication. Duplication may be carried out in many cases with the addition of very little weight, as in the case of making the incidence bracing in a biplane take the full load of either front or rear truss. Struts cannot be easily duplicated, but they are not subject to reversal of stress and are readily inspected. In the case of laminated members, such as spars, fuselage members and wiring plates, a very satisfactory duplication effect is obtained from the fact that they are laminated. These members can generally be designed so that the failure of one or more laminæ does not involve failure of the structure. I certainly disagree with the principle of designing for a higher factor of safety and discarding duplication. I would suggest that a machine with a lower factor and complete duplication of members is considerably safer.

Controls.

The control mechanism is naturally of vital importance and calls for great attention in design both from the aerodynamic and the structural points of view. It will probably be universal practice in the near future to fit ball bearings to all controls. Ball bearing controls are easier to work and do not require constant lubrication, but a more important point is that they obviate backlash. This generally occurs in plain bearing controls, which are seldom lubricated (even if it is possible to do so) and the pilot reports the machine as "soggy" to fly. "Sogginess" generally means a certain amount of "lag" in control and a feeling of lost performance all round. I am strongly of the opinion that this feel is almost entirely due to bad control gear and that the actual performance in speed and climb is unaffected. It has been suggested that as machines get old the performance falls off. I have seen no evidence to support this, and from the few reliable tests that have come under my notice, it is apparent that there is no measurable decrease in performance in a machine that has been in service for two or three years. This is, of course, assuming that engine power and type of propeller are constant and that the weight of the machine has not seriously increased. It would be of great value if practical tests of this character could be carried out at Martlesham or Farnborough. Pulleys and fairleads sooner or later lead to fraying of cables. In cases where the control must be taken round a bend or corner a short length of cycle chain may be run over a smooth pulley with a suitable guard. This has proved satisfactory in practice. If control cables are fitted outside the fuselage, inspection and replacement is easier and the added resistance is hardly measurable. The chief line of development of control gear, apart from mechanical improvement, would seem to be the provision of more ample control at low speeds, especially rudder and elevator control. There is no trouble in making controls effective at high or moderate speeds, but there is room for improvement in their functioning at the lower end of the speed range.

In connection with lateral control, I think it may be of interest to describe briefly a device we have been developing during the past few months. Mr. A. E. Hagg, of our technical department, has been largely responsible for this invention.

The control stick operates chain sprockets located near each aileron through the medium of rods or wires. A crank on each sprocket carries a rod which operates the aileron direct. By setting these cranks at certain angles a differential action is obtained which allows one aileron to move up a greater amount than the other one moves down. This acts as a form of balance, and by varying the angle of the cranks any degree of balance can be obtained. It also has the advantage of reducing lift on the high wing more than increasing lift on the low wing, thus giving less tendency to yaw.

To take full advantage of this scheme the control stick should be high geared to the ailerons so that comparatively small lateral movement of the stick gives full aileron control with very little effort.

This device has been tried out on both monoplane and biplane and the results are highly satisfactory.

Engine Installation.

The detachable engine mounting does not seem to have proved itself necessary in service conditions; it may, however, be found very useful in the future when machines are run harder. It is in any case an advantage during construction and allows different engines to be installed in the same type of machine with the minimum amount of alteration.

Improvements called for in engine installation are of a practical nature and lie chiefly in providing greater accessibility and more robust design of details.

Cowling is always a difficult problem and the best method of treatment is to eliminate it as far as possible.

A matter that calls for immediate attention is the method—or want of method—of starting aero engines. It is not unusual to spend half an hour in starting up in cold weather and this is a serious matter on a commercial service. Electrical self-starters are, I consider, of little or no use and are dead weight to carry about. I see no reason why a suitable hand barring gear should not be satisfactory, providing the ignition and doping systems are improved for starting conditions.

Stability.

A commercial aeroplane must have a good degree of stability so that it can be flown " hands off " under all reasonable conditions. There is, of course, no difficulty in providing this degree of stability, but if the machine is stiffly stable, there will be more trouble in providing good control at low speeds. If the machine can be flown " hands off " under normal conditions, it should be possible to keep right way up when flying in fogs. Most pilots keep direction by steering by ground or other objective visibility (such as clouds) continually checked by compass. The actual process of rudder bar movement is practically subconscious, so that when all objective visibility is removed, as in a fog, the pilot has no guide of direction except the feel of position of the rudder bar. But this trouble will probably be eliminated by the use of a suitable turn indicator and in connection with this it might be an advantage to have a temporary hand-operated rudder control for use in fog conditions.

Petrol Systems.

The best possible petrol system is one in which the tanks can be so placed that the flow is entirely by gravity. Owing to carburettor design it is seldom possible to take advantage of this system as a considerable " head " is required

to ensure sufficient feed when "getting off." It would be a definite gain if engine designers could provide carburettors that would work on a much lower "head" than at present. The pressure system is generally rather lighter and simpler than the petrol pump system, but there is not much to choose between them, and both entail considerably more weight and complication than gravity feed.

The position of petrol tanks on the wings has the advantage of less liability to fire in the air and also in the case of a crash.

Probably the safest place is under the top plane, just outside the slipstream, as this is a part of the wing structure that is often undamaged in a crash.

Rubber joints in the petrol system are undoubtedly a cause of trouble, soft steel piping seems to be reliable and also Petroflex tubing, which has the advantages of a flexible tubing and is at the same time durable.

Accommodation of Passengers.

The passenger cabin is generally arranged with two rows of seats with a central gangway. This is preferable to a three or four row cabin from the point of view of passengers' comfort, owing to all seats being window seats.

The best form of seat at present is the specially designed wicker type. A good wicker chair is light and strong and will stand the wear and tear involved by continually clearing the cabin for carrying goods. When there is no longer any necessity of making a machine to carry both goods and passengers it will be possible further to improve passenger accommodation.

The decoration of the cabin is largely a matter of taste, but at the same time it is most important to have a durable colour scheme that will not be easily tarnished. This is, of course, more difficult when the cabin may also be used for carrying goods. Weight of decoration must be carefully watched.

It is easily possible to throw away 100 lbs. in paint and varnish and this means a loss of from £5 to £20 per day in load, according to the class of freight lost.

The cabin should have a minimum height of 6ft. 3in. and should be clear of obstructions. Ample window lighting is necessary and at least two windows aside should be made to open. An emergency exit of large dimensions is best arranged in the rearmost part of the cabin, as in this position it is well clear of the water in the case of a forced descent.

Engine noise can be considerably reduced by arranging suitable bulkheads between engine and cabin. Exhaust silencing does not present serious difficulties, long pipes with a suitable method for diffusing the gas at the point of exit behind the cabin seem preferable to bulky silencers. Most silencers are very liable to burst when pumped full of petrol vapour when starting up. This is not the case with long pipes.

As there is practically constant air velocity when travelling, it should be possible to arrange for good heating and ventilation systems. Provided heat is taken from a part of the exhaust pipe sufficiently far from the engine, there should be no trouble from devitalised air. It should be possible to provide an ample supply of fresh air with a wide range of temperature.

The luggage compartment should be of large dimensions and entirely separate from the main cabin. It is generally found convenient to arrange it immediately behind the cabin with a door provided in the side of fuselage.

It may be interesting to review the capabilities of a modern type of single-engine commercial machine. I venture to suggest that such a machine has much greater durability than is generally supposed, and that the cost of maintenance of the aeroplane is extremely small. These factors will probably come to light in the immediate future and will no doubt have a healthy effect on the development

of commercial aviation. A modern type commercial machine is capable of hard service for at least three years and probably much longer; taking it at the lower figure this means a distance of well over half a million miles. The present mileage between engine overhauls is from 15-20,000, which compares with any type of motor transport.

As regards maintenance, experience has shown that amongst the chief items of expense are:—

The renewal of control cables owing to fraying.
Replacement of rubber shock absorbers.
Replacement of the wearing parts of petrol pumps.
Tail skids.
Landing wheel tyres.

All these troubles have been eliminated in the latest designs except the last, and the use of solid-tyred wheels is now receiving attention. Maintenance costs should be much less than they were even six months ago.

If we leave out of consideration any aerodynamic or structural improvements that will probably appear in the near future, the result of steady development on normal lines gives every reason for an optimistic outlook. With the appearance of larger and lighter engines the cost of passenger or ton mileage will further decrease, and owing to greater reliability the dangers of forced landings will be practically non-existent.

The London-Paris services will be the subject of much interest during the present year, and it is the experience gathered in running these services that will chiefly govern the future design of the commercial aeroplane.

My thanks are due to Mr. C. C. Walker for his assistance in preparing this paper and especially for those notes referring to the monoplane.

DISCUSSION.

Major F. M. Green dealt first with metal construction, and did not agree with the Author's remarks in this connection. He admitted that at the present moment it was expensive to make metal aeroplanes, because we did not know altogether how to make them. It was very expensive to make wooden aeroplanes at the beginning, and we had to acquire a certain knowledge of technique in the use of wood before we got the weight of wings down to what they were to-day and of the requisite strength. We had already made metal planes which were no heavier than the lightest wooden planes that could be made, and he was pretty sure that we should make planes a little lighter, with the same strength, in steel or other metals. Also, he had reasonable confidence that in the not far-distant future they would be made at no greater cost, and it was even possible they might be cheaper. One of the chief drawbacks to wooden wings was in the cost of the wood itself; a lot had to be wasted in order to pick out the best, and that ran away with a lot of material. As to durability, he did not think we should have any serious trouble in using very thin sheet metals. The sheet metals used were not of paper thickness, as some seemed to imagine, and it was possible to protect them without very great increase of weight. Again, it was possible that we should use stainless steel in the future, which would add to durability, and we could even now afford stainless steel of proper quality at a reasonable price. With regard to multi-engine machines, he agreed that it was no good having a multi-engine machine if they could not fly on one engine. He suggested that a three-engine machine might help, because then, if one engine stopped, they could arrange to have two-thirds of their power, whereas now if one engine stopped, they only had something less than half, because, among other things, there would be increased drag in using the controls

to make an aeroplane fly straight. Twin-engine machines were awkward in many ways. It seemed to him that there were possibilities of using what he might call multi-motor units. By that he meant mounting possibly three engines on a single crank-case in such a way that they could fly on two engines without any extra resistance. That was a problem on which he was working at the moment, and he daresay others had views on that subject. It seemed to him that if they could make a multi-engine unit in which the auxiliaries, such as petrol systems, were entirely separate and distinct, in order that they could use any two engines, they could carry on quite well if one engine stopped because they would then have about two-thirds of the power left, which was about the average horse-power which the average machine to-day flew on. He quite agreed that the reliability of the present machines was considerable; engines did not break down very often, but forced landings did sometimes happen, and on that account pilots would not fly in that particular part of the atmosphere which was most suitable. If they could have engines which were, to all intents and purposes, infinitely reliable, they would be making a great step towards, at any rate, reducing insurance charges in connection with commercial aviation. With the rest of the paper he agreed entirely, and the Author had made a very valuable contribution to the subject.

Mr. W. G. Manning, speaking of landing speeds, said he noticed the Author referred to a machine with a R.A.F. 15 section and a loading of 11.3 lbs. sq. ft., which presumably meant a landing speed of somewhere about 65 miles an hour. He himself had always looked on the question of low landing speeds as being a sort of guarantee against too much damage in the case of a bad landing, caused either by a bad aerodrome or a mistake on the part of the pilot. One remembered that years ago Bleriot built a series of monoplanes with 25 h.p. Anzani engines, and these machines had a very heavy wing camber underneath as well as above. The landing speed was probably about 27 or 30 miles an hour. Lots of people took tosses on these machines, and only in a few instances were people seriously hurt. After that, Bleriot sent out a similar series of machines fitted with 50 h.p. Gnome engines, and with considerably less camber on the wings and with a considerably higher landing speed. If they took a toss out of one of those machines they were almost certainly pretty badly hurt. There was no doubt that if they always assumed a good aerodrome and a perfect landing on the part of the pilot, they could run the speed up to anything they liked. If, on the other hand, they had to assume that the pilot was occasionally going to make a mistake, or that they had to land on a bad aerodrome, then they must not land at too high a speed, because otherwise there would be too much risk of damage both to the plane and to the passengers. He quite agreed with Captain De Havilland on the question of metal construction. Stainless steel would undoubtedly come in the future, and when it came it would remove many objections to metal construction; but he doubted even then whether such things as spars would be completely rustless. It was not easy to see how one was to make rivets, for instance, rustless, unless they were prepared to heat-treat each spar after it was made. Even then it would be difficult, because there would be a certain amount of damage caused on the surface of the rivet by the hammer, and this would result in rust. As one went on, one devised improved methods of constructing wooden spars; wood construction had one important advantage, because it was possible to taper a beam of wood from one end to another, and therefore get ideal conditions of disposition of material, which they could not do with steel, although, to some extent, by rivetting different pieces of metal together it could be done, but it was not quite the same thing. He preferred, for interplane struts, to use steel tubing; as far as his own experience went, steel tube struts with socketed ends were cheaper than wooden ones.

Squadron-Leader R. M. Hill said the paper had appealed to him particularly because of its essentially practical nature, and as a pilot he felt that papers which

keep severely to the practical side help so much. Captain De Havilland had made a comparison between the single and multi-engined aeroplane, and had taken as his text "safety, comfort and economy." They would all agree that safety was the greatest of these, because without that economy lost a good deal of its force. He himself, however, rather felt, if he might be allowed to say so, that the comparison was a little unfair. What mainly concerned the pilot was whether he was going to have a complete cut-out or not. The twin-engined aeroplane was far more liable to a partial breakdown than a single-engined aeroplane, but the chance of both engines going wrong and leaving the pilot in the air without any engine at all was very much less; and he ventured to maintain that the difference between having one engine to help him to glide to some landing space and having no engine at all made all the difference in the world. The greatest danger was when he lost his only engine, and he (the speaker) felt also that the twin-engined aeroplanes they had been largely accustomed to were the war type, which were very heavily loaded, and of relatively high power. The size of a twin-engined aeroplane made it clumsy, and he felt that if they had twin-engined aeroplanes more lightly loaded they would not get nearly the same effect when one engine cut out; and with a certain improvement in aerodynamic design they might get along quite well. The twin-engined aeroplane had a bad time, largely because it was heavily loaded. He (the speaker) could not view with equanimity the bringing up of stalling speeds to 52 and 55 m.p.h.; the pilot's task was already hard enough. He quite realised that it was much more economical to fly with heavily-loaded machines, but to get a short landing run the aeroplane had to be made with a large angle of incidence with respect to the ground. That involved a high undercarriage, and pilots did not like high undercarriages. Sitting in the aeroplane at a large angle to the ground, the pilot had a relatively poor view, and when getting off, if he encountered any ground bumps, the aeroplane felt top heavy. He (the speaker) always liked aeroplanes with low undercarriages, and wings very close to the ground; when landing they seemed to cushion along the ground, and landing seemed much easier altogether. He very heartily agreed with that section in the paper with regard to control gear. He believed that much of the sogginess of controls was due to the haphazard way of fitting them up, and if we had larger pulleys than were used nowadays we should get rid of fraying of the controls, and feel that the controls were working better. Nowadays the pilot could very often not distinguish between a control being aerodynamically imperfect and mechanically imperfect. He endorsed all that was said by the Author as to petrol systems. It should not be necessary for a pilot to sit for three hours trying to learn a petrol system before going up, and it was a considerable mental strain to operate various cocks and to keep an eye open to see that they did not get inadvertently turned off.

Mr. F. HANDLEY PAGE thoroughly agreed with several speakers who had referred to high landing speeds and the consequent increase in the possible danger to the occupants of a machine. He had been discussing this matter with the insurance companies in an endeavour to get premiums reduced, and was informed that if landing speeds could be kept below 50 m.p.h., there was a considerable possibility of lower rates being quoted, as they seemed to be of the opinion that an increase in landing speed was accompanied almost invariably by an increased risk of damage to machines and to the occupants. On the other hand, if they wanted economy at top speed and at cruising speed they must load their machines to a very high degree, *i.e.*, 9, 10 or 11 lbs. per sq. ft. The only solution of the problem seemed to be that of the slotted wing.

He agreed with the Author on the question of metal *v.* wood construction, and he always considered they had an analogy in light boats. They might build a "Lusitania" or other large craft of steel, but practice in connection with motor-boats was almost invariably to build them with wood. In aircraft they must have a body, with a skin to protect the passengers, and if they could make

it one that took the forces and the loads at the same time, then it was possible they might make it lighter while still giving the passengers comfort. That was hardly possible in metal unless they had an ordinary girder structure and covered it with thin material. Therefore he believed on the balance, for the loads to be carried and the sizes of machines at the present time, wood was preferable, and would hold the day for a considerable time over metal. He had been told that during the war the Fokkers which were used in Turkey and other places in the East, where they had very considerable differences of temperature, were built of wood, in a similar manner to those used at the present time, and they experienced no difficulties due to warping or other distortion of the planes, provided the wood was properly treated; he was assured that therein lay a very special secret of the Fokker Company. For some time to come he felt that wood would hold the day.

As to multi- and single-engine machines, to a very large extent the trouble with any engine or engine system lay, not in the engine itself, but in the installation; that was fairly widely admitted. Therefore, if they could get, for a multi-engine machine, a very simple petrol system which consisted of one big tank in the air, with a 5in. pipe and the engine below it, with one tap only to turn off, there was very little to go wrong, and very little chance of the pipe being stopped up (laughter), which was really what they wanted to come to. If they wanted to get the necessary head, the tank must be some distance above the top plane; but if they could evolve a system whereby the engine installation did not require a complicated pressure system or complicated petrol pumping systems, he believed the multi-engine machine would hold the day. The possibilities, then, of anything going wrong were very largely eliminated, and if anything did go wrong they would have another unit to carry on with. The best advantage of all in a twin-engine machine was that the pilot and passengers could have a better look-out than when the engine was in front. He remembered that some passengers who had travelled in a Farman machine—being unable to get accommodation elsewhere (laughter)—commented upon the excellent view they could obtain from the windows at the front, the pilot in that case being in between the planes.

Major R. H. Mayo said that Captain De Havilland was really the pioneer of the heavily-loaded, high landing-speed machine, and when he had the courage to introduce the first DH4 machine he did a service of enormous importance to the Allied cause. The machine was a very great advance on any previous machine of the same type and for the same functions, and it was very largely because Captain De Havilland had obtained such a big increase in performance at the sacrifice of landing speed. For war purposes he had demonstrated that that sacrifice of landing speed was worth while, but he (the speaker) did not think it had been demonstrated that the heavily-loaded machine was the right type of machine for commercial purposes. Since the war, the British designs had been almost exclusively of the comparatively heavily loaded type, and in this country we had had no real demonstration of what a lightly-loaded machine could do. The Author had made a very remarkable statement. He had said, referring to a single-engine, heavily loaded machine, "This type of machine has flown about 1,200 hours on service, and there had never been a mishap which could have been avoided had the landing speed been slower." That was a very fine record, but he did not think it was quite the whole truth. It was certainly true that there had not been many accidents, but what had been the effect of this high landing speed on the regularity of the service? How many times had journeys between London and Paris to be cancelled because the machine was not suitable for the journey under adverse weather conditions? Of all the conditions that were difficult to deal with on this particular route, fog was the worst; this winter we had had a spell of many weeks when fog was prevalent, and the services had been very seriously interrupted. He ventured to think that fogs were not

an insuperable difficulty, but that many modern machines were too dangerous to negotiate a forced landing in foggy conditions. The fact of the matter was that the pilot knew he would have to fly at a low altitude, and if the engine failed he would probably have to land in a very limited space, which he could not do safely on a heavily-loaded machine. He knew that on an aerodrome he could pull up in, say, 163 yards, or whatever it was, but to achieve that on a forced landing across country, where there were probably obstructions, was a very difficult matter. There was no stretch of country between London and Paris where they could hope to negotiate a forced landing with a machine landing at 60 miles an hour with any reasonable degree of certainty. That was the thing that was in the minds of the pilots, and it had the effect of enormously reducing the regularity of the services. That irregularity was a very serious handicap. Only when services ran systematically, whatever the weather, would the public have confidence in them, and although fog would always be difficult to cope with, the difficulty would be very greatly reduced when we had machines with reasonably low landing speeds. During last year he had had a good deal of experience with the French machines, and one machine in particular had given a very good demonstration of the value of low landing speeds; that was the Farman "Goliath," which had easily the lowest landing speed of all the passenger machines now operating. Although numerous engine failures had occurred on this type of machine, it had a remarkably good record on all the services, for the reason that it could negotiate forced landings. As an illustration of what the machine could do, Major Mayo mentioned that during the competition for the French Grand Prix last year the "Goliath" was forced to land by engine trouble in very broken country at night without landing lights and without any external assistance. It landed successfully, but only because it could land slowly. The pilots had to negotiate altogether three such forced landings at night during the circuit of France, all of which were successful, and eventually this machine won the prize. That was rather a severe test, but it showed what could be done with a machine of low landing speed, and that such machines would be able to face foggy conditions on recognised routes in the day-time.

The Farman "Goliath" illustrated a remark made by Squadron-Leader Hill, which he (the speaker) thoroughly agreed with—that the value of a multi-engine machine would depend to a great extent on the aerodynamics of the machine and on the question of loading. This was a case in point; the Farman "Goliath" was a twin-engined machine, and that fact had been of very great value, largely owing to the machine being lightly loaded. He had been talking, a few days ago, to a French pilot who had started from Rotterdam for Brussels. Five minutes after starting one of his crankshafts had broken, but he was able to carry on with his full load for a distance of over 80 kilometres and land safely at Brussels. That showed how a lightly-loaded machine could make use of the fact that it was a multi-engine machine; in point of fact, the second engine had often just made the difference with such machines.

Referring to petrol installations, he remarked that in France the gravity tank had been almost universally adopted; nearly all the post-war machines had gravity tanks on the top planes. But that was not necessarily a safeguard against fire, unless the details of the installation were carefully attended to. He gave an illustration of how a machine had recently been destroyed by fire due to faulty installation, in spite of the fact that all the petrol was contained in tanks on the wings and well clear of the fuselage. In this case the pilot had not been provided with an adequate means of shutting off the petrol after the fire had started.

Colonel W. A. Bristow dealt with the conditions in commercial machines for the pilots, and said that he would like to see pilots in the middle of the cockpit, so seated that they could see equally well on both sides of the machine. The present conditions were a great drawback when taxying, because some aero-

dromes to-day were very imperfect. It was also very difficult for a man who had to make a forced landing on a single-engine machine when he could look only on one side. Having got the pilot fixed in a position so that he could see well on both sides and in front of the machine, they had to consider the first essentials for safe operation. There was first his compass. After seating him in a good position in relation to the controls, which should be adjustable, because there was a very great difference in the size and length of reach of commercial pilots to-day, and providing him with a compass in a place where it could be easily read in all circumstances, the question of the wireless gear arose. Generally, when a machine was finished, an engineer came from Marconi's and tried to find a place to put the gear. He would hang it all over the cockpit, like a Christmas tree, and then the pilot must take a mechanic because he could not wind out the aerial himself. The wireless installation should be so arranged that the pilot could work the whole thing himself, and he (the speaker) was sure that they would not get the best results out of wireless on aeroplanes until the pilot could work the installation himself. The good results obtained with high landing speeds were probably due to several reasons which really should not be allowed to persist. In this country very good results indeed had been obtained from the operation of, for instance, the DH18, which had proved itself to be safe in operation. But there was the fact that we had reduced commercial aviation in this country to almost a highly specialised science. The requirements of the machines had reduced commercial pilots to an extraordinarily small number, and it was becoming an extraordinarily difficult matter to find a pilot that we knew would be perfectly safe in all weathers in some types of machines now operated. In France there was one line operating a heavily-loaded machine, which had 15 per cent. forced landings over six months. The number of machines that crashed was appalling, and there were several fatal accidents. Another machine, the "Goliath," which had 14 per cent. forced landings over the same period, had not recorded, so far as he knew, a single injury to a passenger, and there the pilots were far more numerous, and, in the main, not what one would term the highly specialised first-class pilots of which our little band of pilots in this country consisted. Something would have to be done to make the operation of machines more comparable with the working of high-speed locomotives, or a ship. There was no doubt that the number of journeys which could have been undertaken had been very seriously curtailed by the fact that the machines available were not of the type that could be safely sent off with passengers in the sort of weather they might have had to encounter.

The CHAIRMAN said they had had two or three acutely interesting problems put before them by Captain De Havilland, but one was perhaps more acute than the others, namely, that of the heavily-loaded machine *v.* the lightly-loaded machine. That would resolve itself practically in the future, because he believed the Author's scheme was the scheme which would eventually take its prime position when the power unit no longer broke down. No argument had been urged against the heavily-loaded machine, except that the engine was liable to stop, so far as he could gather, and therefore it was just as well that they had amongst them an engineer of foresight who was working for that time. The other big question of metal *v.* wood was raised, and he did not think that in this case the issue was joined quite so strongly, but his personal view favoured Captain De Havilland's, partly because he thought it would be essential for many years to come that civil machines should be convertible into war machines, and for war machines a high rate of replacement of wastage was cardinal, and the rate at which they could work on wood was incomparably greater than that at which they could work on metal. He defied anybody to rivet up a wing at the same rate as that at which they could build up a structure in wood.

Captain DE HAVILLAND, replying to the discussion, dealt first with Major Green's remarks as to metal construction. He quite agreed that metal con-

struction would eventually find its place, but the trouble now was that the time factor was important, and he should think that metal machines must take three times as long to build as wooden machines. There was no doubt that they were very much more difficult to build unless they had quantities running into hundreds probably, and that was very unlikely for a very considerable time. But wood had other advantages, and there was one big advantage in the case of a wooden machine if it were far away from its place of manufacture. A metal machine was much more difficult to repair than a wooden machine; if a wooden machine needed repair they could generally get the wood and a man to repair it, which was not the case with a metal machine, especially when using high-grade steels, which were difficult to obtain. He had not heard anyone really give a reason why machines should be of metal, except for use in the tropics, where it might be essential, but in normal climates there did not seem to be any great call for metal at present. Above all, in these times commercial machines must be cheap, otherwise it would be difficult to start any air lines at all. Major Green had also mentioned multi-engine machines. He was glad to hear that he was working on a multi-engine unit because that was another line of development which would probably bring good results. But if one set out to design a commercial machine at the present time, one could hardly consider a multi-engine unit because none existed in a tried-out form. Mr. Manning had spoken of landing speeds. It was a difficult question, but it seemed to him that machines with a loading of 10 or 11 lbs. per sq. ft. (R.A.F. 15 section), which certainly had a touching speed of 63 miles an hour, were not anything like so dangerous as some speakers had suggested; really the proof was in the experience we had had during the past two years of highly-loaded machines flying daily on the London-Paris service. Certainly there had been very few accidents, and he knew there had been several forced landings successfully made in fairly small fields. One would naturally go for a landing speed of 20 miles an hour if possible, but it would be very difficult to make a cheap or fast machine. Squadron-Leader Hill had mentioned a large ground angle as being bad. He (Captain De Havilland) really did not think there were any disadvantages in the big ground angle as the pilot would soon get used to it. To look at the matter of high loading from the point of view of high landing speeds was rather the wrong way to look at it. After all, the main thing was the run after touching the ground. It did not matter very much whether you touched at 50 or 60 if you ran practically the same distance. It would be quite interesting to test the run of a highly-loaded machine with a big angle against another machine with a reasonably light loading. He believed it would be found that a highly-loaded machine with a big angle would pull up in almost the same space as the lightly-loaded machine. Mr. Mayo had also discussed high landing speeds and the danger of fogs. He (Captain De Havilland) believed that in a bad fog any machine was dangerous, and there again he did not see that it mattered very much, if they were going to hit the ground in a fog, whether they hit it at 50 or 63. In any case it would be rather bad, and if the actual run was very little greater in the heavily-loaded machine he did not see any great difference. As to the Farman machine which was said to fly with full load on one engine, did anyone seriously believe this was possible? As to gravity feed, it would be a great advantage if engine designers could so design carburettors that they would work at a head, say, of 6in. instead of 3ft. In most ordinary-sized machines it was almost impossible to get the petrol tank high enough, and therefore they had to go back to the application of pressure or pump feed. They found that where a head of 2ft. was specified as being sufficient the acceleration of the machine generally upset the flow, and it really meant a head of more like twice the amount. With regard to Col. Bristow's suggestions that better provision should be made for pilots, the one trouble in putting the pilot in the middle of the cockpit was that very often the navigator was wanted at the side of the pilot. That had been often specified and made it very difficult, because the pilot had to be put at one side. As to compasses and wireless gear,

he could only suggest that in the latest machines that had been designed they were in a better position.

A hearty vote of thanks to Captain De Havilland terminated the proceedings.

NOTES ON CAPTAIN DE HAVILLAND'S PAPER.

There are several statements in Captain De Havilland's interesting paper which are distinctly debatable..

The first is the relative cost and reliability of a large multi-engine machine compared with a number of small single-engine machines of the same total carrying capacity. The large machine is fundamentally cheaper per lb., as the number of manufacturing operations will be smaller; actually the number of large commercial machines constructed has been so small that they are practically all experimental models.

Regarding reliability, this, in a multi-engine machine, depends on the number of engines and/or the horse-power loading of the machine. It is not commercially economical to make a twin-engine machine that can be flown quite readily by any pilot with one engine cut out. It is possible to make such a machine with three engines, and such a machine should be practically immune from forced landings due to engine failure, but as the available reliable engines are of large horse-power, it is doubtful whether the resulting aeroplane would not be larger than wanted at present or for some time. Regarding landing speed, it is obvious that the lowest possible landing speed is required, but it must be remembered that in the case of a large machine that has to be flown straight on to the ground (*i.e.*, cannot be side-slipped to lose height) reducing wing loading to reduce landing speed may produce a machine more dangerous to land than the heavily-loaded machine. It would appear that with, say, R.A.F. 15 section wings that at loading of 9.5—10 lbs. per sq. ft. gives a reasonable landing speed with a sufficiently steep angle of glide to enable a landing to be made in a confined space without spoiling the get-away and climb. The ability to make safe landings in restricted areas is governed by many other considerations than the actual speed at which the machine touches the ground, such as type of undercarriage, length of run to pull up, etc. Captain De Havilland's figures for pull-up can be bettered with considerably smaller incidence.

I certainly agree with Captain De Havilland as to wood construction. Metal construction will be used as soon as the type of construction available is worth using. Such type will be quite different from any at present developed, and it is obvious that for some years wood construction, which has not even yet reached its full development, will be used.

Regarding controls, I consider that the cable pulley has been much maligned. If the pulley is of adequate diameter, of correct section groove and properly mounted, a cable will run safely for hundreds of hours. The fairlead, however, is much more dangerous, and should be eliminated as far as possible.

W. T. Reid.

NOTES ON THE STORAGE OF AIRCRAFT.

BY P. V. HOARE, A.F.R.AË.S., A.M.I.C.E., A.C.G.I., D.I.C.

(Concluded from last month.)

HANDLING AND HOUSING AIRCRAFT.

Before storing an aircraft, it has to be housed, and this in turn gives rise to various operations of handling, in which each type of aircraft calls for particular detail. It is now proposed to consider the questions of housing and handling for each of the types of aircraft given as typical examples for storage.

As for storage, there again appears general facts which may apply equally well to all types of aircraft, and then particular treatment for each type.

With a large type of aircraft a good deal of care is necessary in handling during the process of getting it into and out of the storage shed. The difficulties then experienced will be increased in windy weather, but these may be overcome by increasing the personnel of the handling party. It is not within the scope of these notes to discuss how such a party is organised, but only to indicate the parts of the various operations which require attention to avoid damage to the aircraft. In Fig. 17 is shown a typical case of a large aircraft being hauled on the aerodrome, and in this instance a caterpillar tractor is used to tow the aircraft, while its tail is carried on a trolley.

FIG. 17.—*Handling a large Aeroplane on an Aerodrome.*

Most large aircraft of the present time are designed so that their main planes may be folded, and this is usually done when the aircraft is in store. For convenience, it is usual to fold the main planes before the aircraft enters the storage shed. It is not possible to describe in detail the folding of all large types of aircraft, so as an example that of the Handley Page 0.400 will be taken.

Assuming the aircraft is placed with its tail on a trolley, the jury struts are fitted into their respective positions between the spherical seats provided on the front spars, and each strut is adjusted in length until it is just tight. Remove top and bottom hinge pins by means of the handles provided, having first removed the locking pins. The main planes may now be allowed to swing back

gently into their folded position, and they may be steadied by means of short ropes attached to the mooring rings on the under side of the wing tips. Next place the distance pieces in position between the main planes and the fuselage. The aircraft is now in a condition suitable for movement into the storage shed.

Before taking the aircraft into the shed it is advisable, where any doubt exists, to ascertain that the roof clearances and side clearances are sufficient to accommodate the machine in the position proposed for storage. This may be done either by simply taking measurements of the overall dimensions of the aircraft and corresponding measurements of the storage shed, or by erecting a light wooden structure to indicate the overall dimensions of the aircraft, and moving this structure about inside the shed until the most suitable position for the final location of the machine has been found. In this way it is sometimes possible to obtain a more efficient distribution for storage, and the exact location of each aircraft in the shed is defined before storage is commenced, which is an advantage, as the space available for movement when the storage shed has several large machines inside is very limited.

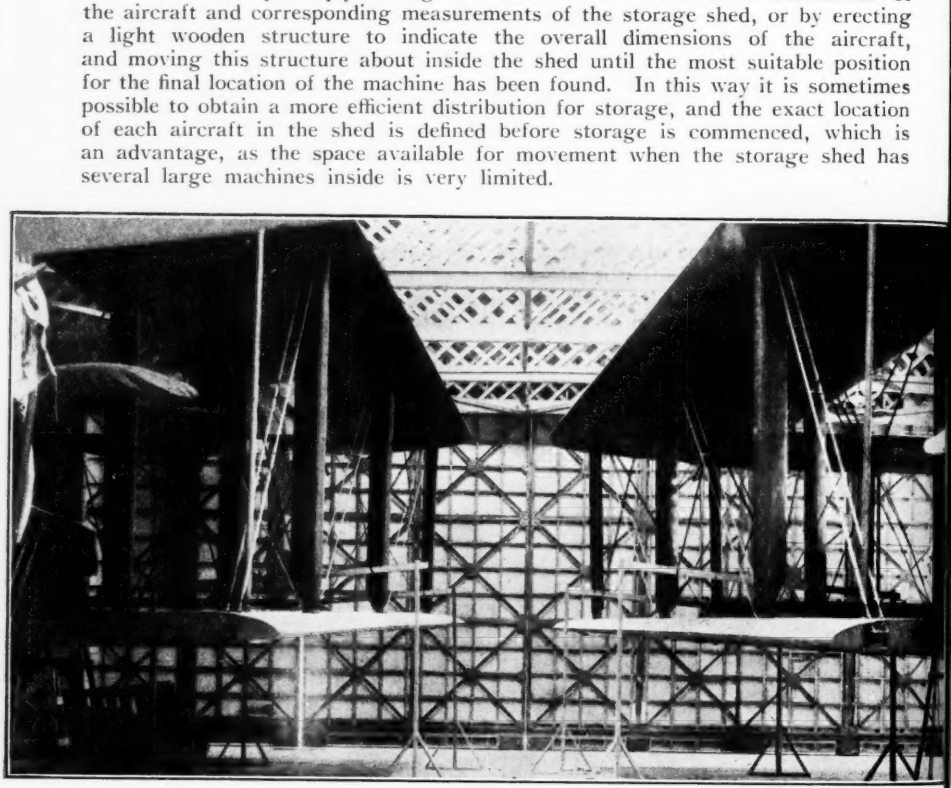

FIG. 18.—*Clearance between leading edges of Main Planes.*

The weight of a large aircraft is fairly considerable, usually several tons, and it should be remembered that when this mass is set in motion it is not easily arrested. This has bearing upon the entry of the aircraft into the shed, and where the clearances are small, the aircraft should approach the entrance of the shed very slowly, at the same time men being posted to the distant positions, such as the leading edges of the main planes when they are folded, and the top of the upper main plane, to give a signal if any part of the aircraft is likely to foul the shed; a comparatively slight bump is quite sufficient to damage a main plane almost beyond repair.

When the aircraft are in the shed freedom must be given for the movement of a particular machine either for purposes of inspection or for its removal from the shed. Such movement will therefore call for a degree of clearance between

one aircraft and another, and the magnitude of these clearances must depend upon the type of aircraft being dealt with. With low built wooden sheds the most troublesome are probably the clearances necessary between the roof of the shed and the top of the aircraft, and in some cases the roof trusses are of such design that they give less head clearance at their supports than they do at the centre of their span. Having regard to this fact, it is not expedient to leave the aircraft in such a position in the shed that if it is moved slightly forwards or backwards on its wheels it will run into a position of less clearances, *i.e.*, the aircraft should not move parallel to the roof trusses. In Fig. 18 is shown a typical clearance between the leading edges of the main planes with the aircraft folded.

As previously mentioned, various supporting devices are used for the accommodation of the aircraft in the shed, and where an aircraft of a given type has once been conveniently located it will be useful if the positions of the supporting devices are marked on the floor. For this purpose the floor may be marked with whitewash where each of the supporting devices occur, so that when another aircraft of the same type is to be stored the supports may quickly be placed in the correct positions and the aircraft moved until it registers with the supports. The correct clearances are thereby ensured and time is saved in the operation of storage.

Continuing now to the small types of aircraft.

These are sometimes fitted with folding wings, and as an example of the work involved, the detail of folding for the Fairey seaplane will be outlined.

To fold this type of aircraft the control column should first be adjusted so that the elevators are in line with the tail plane and the rudder in its central position. The quick release fittings which will be found at the following points are then disconnected:—

(*a*) Main plane drag wires.
(*b*) Wires from main planes to chassis.
(*c*) Rear outer frame side bracing wires.
(*d*) Aileron connecting cables.
(*e*) Wing flap connecting cables.
(*f*) Aileron cables at outer levers.

When (*d*), (*e*) and (*f*) are disconnected, the upper ailerons and wing flaps will be pulled upwards by their elastic return cables in the control system and the lower ailerons and wing flaps will drop down, thus reducing the chord of the main planes and allowing them to come closer to the sides of the fuselage. The jury strut between the roots of the front spars of each of the main planes is then inserted and its bracing connected; withdrawing the locking pins on the front spar end fittings allows the main planes to be swung back on their rear spar hinges. When folded, the main planes are secured by two catches placed one on each side of the bottom longerons and these catches engage with steel pins on the rear outer interplane struts. It is important that no folding should be attempted until the jury struts with their bracings have been inserted.

As discussed previously, the operations of placing small aircraft in the storage shed do not present so many difficulties as the larger types, their lightness and smaller form admitting of more freedom in handling. Care is necessary, however, particularly with the wing tips, as in cases where the wings do not fold, and men should be posted, one at each wing tip, while a machine is entering the shed. It will be found convenient to locate the smaller types of aircraft in positions head to tail alternately along the shed, but not so close as to allow the main planes of one aircraft to foul the tail unit of the adjacent one. The general idea of such a layout can be seen by referring to Fig. 12, where the aircraft concerned are of the Sopwith Snipe class. As before, the positions of the supporting trestles and packing blocks for the undercarriage may be marked in whitewash on the floor of the shed, and a clearance zone similarly outlined

round each machine to prevent persons from walking into parts of the external bracing, such as drag cables from the front of the fuselage to the outer interplane struts.

The manipulation of boat and float seaplanes, so far as movements into and out of the shed are concerned, is similar to that employed for aeroplanes. The inability of the aircraft to travel over the ground is overcome by placing it on a suitable cradle, or trolley, designed to meet the particular needs of the aircraft. When the seaplane is in position on its cradle or trolley it may be regarded for handling purposes as an aeroplane. The trolley for a float seaplane and the cradle for a boat seaplane have been previously described.

In addition to the clearances which have been outlined above and are necessary for the safe movement of a particular machine within the shed, it is also necessary to have unrestricted access to most parts of the shed in case of fire. The most important factor in this is a clear floor space, and when aircraft have been correctly supported and stored in the shed, all unnecessary loose objects should be removed. Reference to Fig. 18 gives an idea of what is required in this direction, although in this illustration no fire extinguishers are shown. In practice, fire extinguishers should be located at several accessible points in the shed, and an adequate supply of sand should be available to work in conjunction with the fire extinguishers. In the case of collective storage of aircraft a clear floor space is not possible, but gangways between the various machines should be kept quite clear. In Fig. 12 an arrangement for fire extinguishers is shown, but no hard-and-fast rule can be laid down with respect to this matter, it being based only upon the circumstances of each particular shed. A convenient allotment of fire appliances is one extinguisher per 1,000 square feet and one bucket per 2,000 square feet of floor space. The buckets may be used for either sand or water as desired.

COMPONENTS.

In considering the storage of component parts of aircraft it is intended only to deal with the sub-divisions which occur in general use and not with detailed dismantling, such as the dismembering of a fuselage into its struts and longerons. For prolonged storage, aircraft may be accommodated in a much smaller space when they are separated in components, but it follows that the subsequent erection must necessarily take longer. One or two fundamental principles should be borne in mind in this matter, the chief being that when an aircraft is dismantled it is always advisable for the components to retain their association with each other. Therefore a system of distinctive labelling should be formulated as a means of identification of the various parts and to ensure that a particular aircraft is re-erected from the correct components. In this way many minor details of fitting will be avoided, as although the various parts are designed to be interchangeable, yet when reduced to detail, matters such as the fitting of locking pins in their holes may be facilitated by knowing that a particular pin will, without alteration, fit correctly. Further, with the aircraft in the dismantled condition, the components are more easily handled and there should be less liability for damage to occur than when the complete aircraft is handled as a unit.

It is proposed now to sub-divide the aircraft under the headings of its components.

Fuselages.

In the case of a small aircraft the fuselage is usually considered as a single component and may be either of wood or metal; in the former there is a possibility of dismembering the parts, whereas in the steel variety, the individual members are usually inseparably attached to one another. The possible methods

of storage for the wooden fuselage are therefore greater than the steel ones, but as mentioned previously, the sub-division of the components is rarely carried out.

Fuselages of large aircraft are mostly designed so that they may be split into sections, an example of which occurs in the case of the D.H.10 aeroplane, where there are the front, middle and rear portions, each of which can be considered as a component and their detachment from each other readily carried out. It will be convenient, therefore, to regard the sections of a large fuselage on the same lines as the complete fuselage of a small aircraft.

Fuselages are necessarily long and comparatively narrow structures, and whether of wood or metal they are subject to deformation under loading, which movement may in time become a permanent change of shape and of such magnitude as to render the components unfit for further use. This fact calls for the adequate supporting and simply to support fuselages at each end will not usually suffice. Provision must be made to prevent sagging, and the best way to overcome this is to arrange several supports throughout the entire length of the fuselage and to place these supports under cross bays of the structure. Sagging is a particular tendency of built-up members, such as those of McGruer construction, and fuselages embodying this principle should be supported at many points throughout their length. The supporting points, too, should be arranged so that they each carry their particular share of the load, as one high point, in a system of supports, is as detrimental as a lack of support at that particular place.

With these conditions borne in mind, the fuselages or sections of fuselages may be placed horizontally and stored either singly or one above the other according to their weight, thus the complete fuselage of a Handley Page aeroplane would be stored singly, as to place one above the other would involve too much load falling upon the lower one, in addition to the great difficulty which would be experienced in placing them in position in storage sheds not having overhead gantrys. For the same reasons it is not expedient to store more than three small fuselages one above the other.

The weight on the lower fuselage could, of course, be relieved by constructing racks which carry each fuselage independently, but the difficulties of placing the upper ones in position and of carrying out satisfactorily the periodical inspections more than outweigh the advantages which may accrue from rack storage. A typical method of supporting large fuselages from the floor of the shed is shown in Fig. 19.

To avoid damage by the supporting members, the loads should be carried on pieces of felt or other soft material, and in cases where longitudinal members are supported in an inclined position, wedge-shape packing should be arranged on the supports so that the member is not bearing on the edge of a trestle.

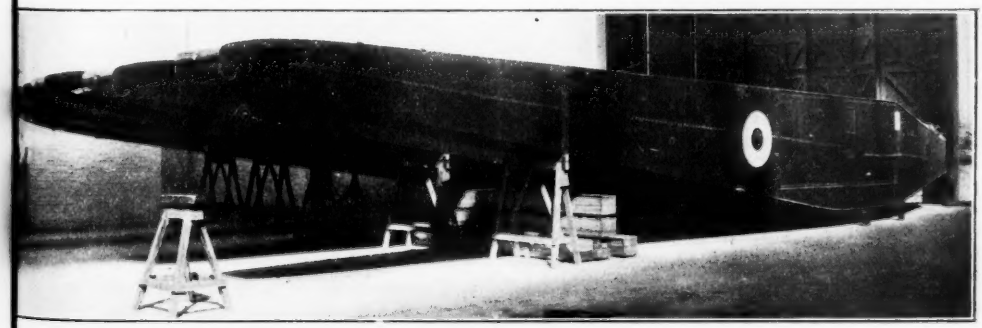

FIG. 19.—*Handley Page O/400 Fuselages in Store.*

The actual dimensions of supporting trestles or racks need not be defined, but if timberings of substantial size are used so that the supports can carry a large fuselage, these same supports may be used, suitably spaced, to carry smaller fuselages, thereby reducing the number of different types of trestles which have to be constructed.

In cases where fuselages have their fabric coverings laced on, it is better to remove these coverings so that periodical inspection of the structure may be easily carried out. If the entire fabric cannot be conveniently removed, such portions as are laced in position should be taken away. The metal fittings of the fuselage should be treated to prevent corrosion by being first cleaned down and any traces of rust removed, and afterwards coated with a suitable grease compound to exclude air from the entire fitting. The grease should be evenly and thoroughly applied to prevent corrosion from commencing and extending under the grease film. In applying this protective coating, care should be taken to prevent it from being placed on fabric, as the constituents of the grease have a deleterious effect on the dope film. The metal bracing wires of the structure should be similarly coated. In cases where a large fuselage has been separated into its several components, any bare end grain of timber should be varnished over.

Hulls.

Seaplane hulls may be regarded as analogous to fuselages of large aeroplanes, but unlike these, they are usually not separable into components and so cannot be subject to the conditions of intensive storage. Their shape also does not lend itself to such simple methods of supporting as are employed for a rectangular fuselage. A hull stripped of all its fittings can be accommodated either in a cradle or on specially constructed trestles, and although these components are of more rigid construction than fuselages and not so liable to sag or distort, yet to retain their efficiency they must be maintained watertight. The main points in their storage are therefore suitable supports and an adequate means to prevent the hull from becoming leaky.

Dealing with the question of supports, the easiest and probably most convenient method is to employ a mobile trolley, similar to that used for the complete aircraft, and where a sufficient number of these trolleys are available the hulls may safely be placed upon them and left thus supported in the desired positions in the storage shed. If the hull is likely to remain in store for some time it is advisable to pack up the bow and stern on trestles to prevent sagging of these overhanging portions. The supporting surfaces of the trolleys consist of cross battens which are spaced about 2in. apart, thus allowing free access of air to the underside of the hull.

A trolley is shown in Fig. 11 and may be used either for beach work or for storage of the hull. As an alternative to this cradle, the hull may be supported on three cradle trestles as shown in Fig. 20, and these will be found convenient where mobile trolleys cannot be spared for storage work. These cradle trestles are placed, one under the edge of the front step, another about 6in. aft of the main spar attachments, and the third under the tail end near the tail plane strut attachments, thus leaving the entire bottom of the hull exposed. They are constructed of heavy timberings with their bearing surfaces about 12in. wide and heavily padded to prevent injury to the hull. In front view they are V-shape, and the apex of this "V" is cut away to give clearance for the keel; these supports are strong enough to carry the complete aircraft if necessary.

There may appear a little difficulty in placing hulls on these trestles, and in the operation of moving the hull from the trolley to these trestles the tail is first pulled down so as to raise the front portion just clear of the trolley; and in this position the front trestle is placed under the hull and close to the

trolley. The hull is then lowered on to the front trestle. By raising the tail on the front trestle the trolley can be run clear and the centre trestle placed in position just aft of the rear spars and the hull lowered on to both trestles. This operation can be carried out either by man-handling the hull or by lifting from an overhead gantry where such exists. Owing to the weight of the hull and the size of the supports, it is not possible to adopt any method of rack storage as used for certain fuselages.

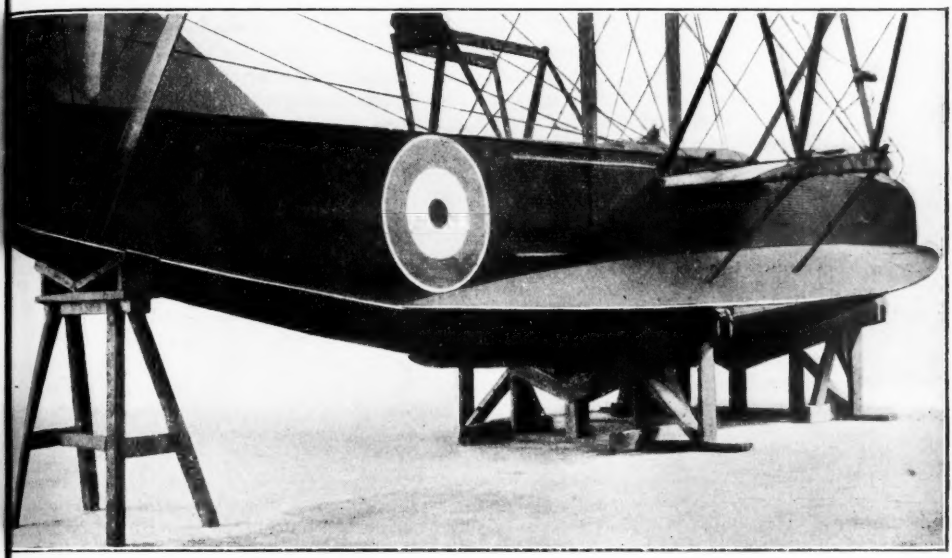

FIG. 20.—*Seaplane Hull on Cradle Trestles.*

To prevent shrinkage of hulls certain methods are adopted, one of which has been previously outlined. To this end also hulls may be washed down periodically with fresh water at times, dependent largely upon the weather; but as often as is necessary to keep the hulls damp. In this case drain plugs should be kept open until the hulls are wanted. Another method of maintaining the hulls watertight is to close the drain plugs and place a quantity of fresh water inside each hull and allow it to remain there during storage. This water should be changed at intervals. When this method is used the weight of the water used must be borne in mind when arranging the supports for the hull. If during storage the planking shows signs of shrinkage a coating of thin varnish should be applied, the joints having been previously filled with white lead. After a hull has been cleaned down and made watertight, dust and dirt may be excluded by fitting a cover over the whole structure. This cover should be readily detachable to facilitate the periodical operations on the hull. All metal fittings which are permanently attached to the hull should be carefully avoided when the water treatment is applied and before storage is commenced they should be properly cleaned and coated with grease or painted.

When stored in sheds which are heated during the winter, hulls must be kept clear of all heating appliances and in sheds of corrugated iron they should be placed at least four feet from the sides of the shed. It is also advisable to prevent direct access of sunlight to the hulls.

Main Planes.

In dealing with the storage of main planes it is proposed to consider these components as separate units, with the centre section planes excluded, and with the ailerons (and wing flaps in the case of the Fairey seaplane) removed. In general, these components are more convenient to store than fuselages, but their frailty calls for careful handling, which in turn is rendered more difficult by their size.

There are three possible ways to store a main plane, namely, resting on its leading edge with its chord vertical, lying with its spars and chord horizontal, or resting on its spar ends with the spars vertical.

These methods have been enumerated in the order of preference, having regard to convenience of storage and liability to damage. With the first two methods the space required for accommodating planes will be governed by the length of the shed, while the third method necessarily calls for roof clearance; it may be added too, that in the case of a main plane of a large span, storage by the third method becomes impracticable owing to the difficulties in handling the component. This method may, however, be used for main planes of small aircraft.

Taking firstly storage with the leading edge horizontal and the chord vertical. The general factors entering into this case are, that the leading edge of a main plane is very fragile, and again, a considerable area of taut fabric is exposed to damage from the side. It is therefore not advisable to carry the whole weight of the main plane on one or two points of support under the leading edge, as a small lack of adjustment of these supports or the interchanging of one type of main plane for another on the supports, would probably entail damage to the leading edge. The fabric surface is most liable to damage by the fittings for the main plane bracing wires, which project slightly from the surface of the plane, so that each plane should be carefully confined by adjustable clips to prevent it from rolling over on its leading edge. The supports for the leading edge should preferably extend throughout its whole length, and because the plane is slid into its position in the rack, these supports must be felt covered and free from any projections. In Fig. 21 is shown a main plane storage rack, which conforms to the above conditions. In this instance, the planes are supported on planks which are raised just clear of the floor and are covered with felt. The rack is divided into bays, each of which accommodates one pair of planes, so that the association of the planes for a particular aircraft may easily be maintained. To prevent one plane from rolling against another, adjustable " V " shaped packings are placed over each trailing edge, and the planes are arranged with the lower surfaces of each pair facing one another. Racks of this description may be used to store several different types of planes, and the upper portions of the racks may be used for other purposes.

It is obvious that these racks must not completely fill the storage shed, as clearance is necessary for placing the planes in position; they can, however, be placed so that they face the doors of the shed, in which case the planes may be entered or removed by opening the shed doors, thereby obtaining the necessary clearance. Their actual location in the shed will therefore be determined by the design of shed, but where possible they should not be backed on to a blank wall, as this conduces to an accumulation of dirt between the wall and the rack and a tendency to harbour vermin, both of which are undesirable and can only be removed by emptying the entire bank of racks.

The second method of storage, that is, with the main planes lying flat and their spars horizontal, introduces many of the features of the previous method, but in this case the storage racks are horizontal, and the weight of the plane normally rests on the spars, which, being strong members, need not be supported

throughout their entire length. Now this is easily done with planes of a flat aerofoil section, but when dealing with those of the high lift variety, that is, of considerable camber, they would, if placed on the flat surface of the rack, rest only on their leading and trailing edges. The rack therefore must either be cut away to allow these edges to overhang, or with the rack of width equal to the length of wing chord, the supports for the spars must be raised above the level of the rack. In placing the planes in position, the projecting parts of the main plane fittings do not allow the planes to be slid in position. These projections must be lifted clear of the supports, and the work involved, therefore, is slightly greater than with the former method, as a particular plane has to be lifted at both ends and then lowered on to the rack. The supporting members of the racks should be felt-covered. With this method of storage the planes are racked separately, which increases the storage space required as compared with the previous method. The height to which planes may be stored in this way is

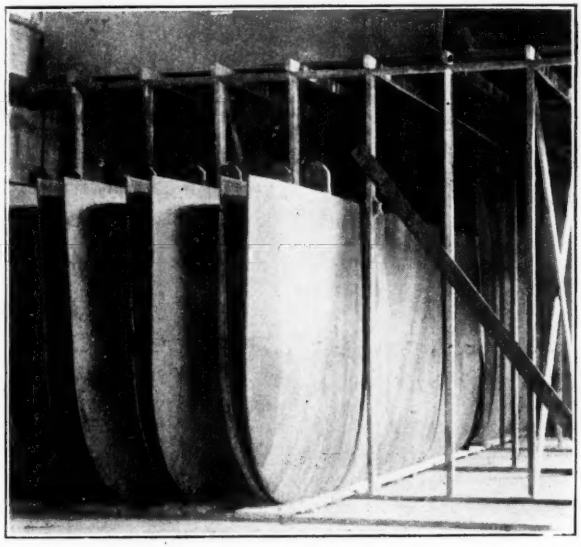

FIG. 21.—*Main Planes stored on leading edges.*

governed by the accessibility of the racks, but in practice, difficulties will be experienced in taking them higher than the reach of an average man. Each plane should be distinctively labelled to show to which aircraft it normally belongs.

The other alternative method of storage is with the spars of the plane vertical, and is practically limited in use to planes of not more than 15ft. span. In this case the load is carried on the ends of the spars and end rib, supports being arranged slightly raised from the floor and so that they lie under the ends of the spars. Provision must also be made to prevent one plane from rolling into another. In Fig. 22 are shown planes stored in this position, and in this case, each plane has its separate compartment defined by cross battens at the top of a rack. The battens may be substituted by strips of webbing if desired, but the former is preferable, as the webbing is liable to break, and is really only used in the absence of better material. The main planes in this instance are shown with their ailerons attached, but they may be accommodated in a much smaller space by removing the ailerons, which dispenses with the projecting

aileron levers. In sheds where sufficient head room is available, this method probably leads to more compact storage than the previous ones, and not such a large horizontal clearance is required for placing the planes in the racks. In large storage sheds it will be found convenient to place this type of main plane rack round the walls of the shed, as the back of the rack may easily be seen and is accessible for cleaning purposes.

Control Surfaces.

For purposes of this section the control surfaces will be considered as comprising the tail plane, fin, rudder, elevators, ailerons, and wing flaps.

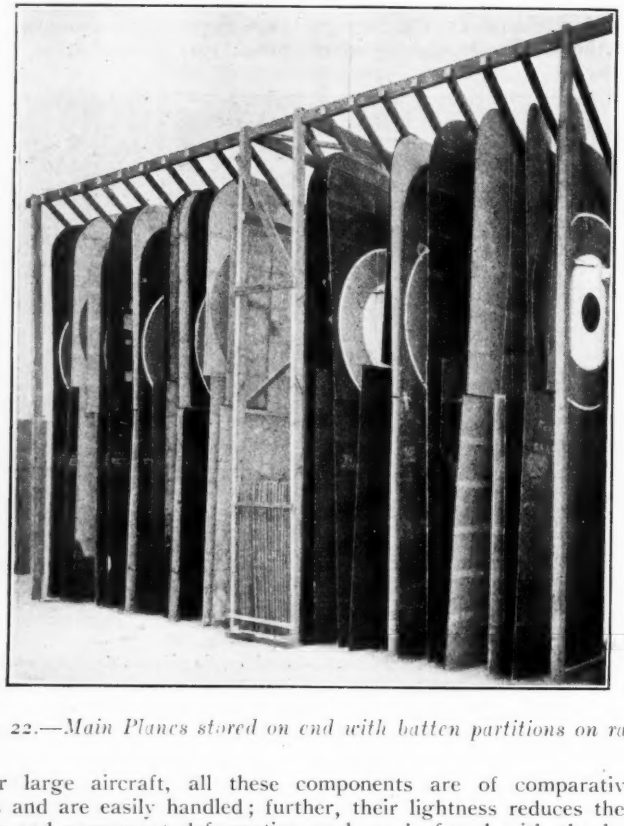

FIG. 22.—*Main Planes stored on end with batten partitions on rack.*

Except for large aircraft, all these components are of comparatively small dimensions and are easily handled; further, their lightness reduces the tendency to sagging and permanent deformation such as is found with the larger components. The small size of these components also permits their being accommodated in any convenient space in the storage shed, and usually without any special design of rack. Where main planes are stored with their spars horizontal, these smaller components may be placed on the top of the plane racks, arrangements being made for the parts to maintain their association with one another, either by a system of labelling or by placing together a whole set common to one aircraft. It should be remembered that these parts have the inherent frailty of the larger surfaces, and damage may easily occur through careless handling. The elevators, rudders and ailerons have rigidly attached levers which project

nine or ten inches at right angles to the fabric surface, consequently a clearance for these projections has to be allowed when calculating the storage space required, and when placing one surface against another. When it is likely that these parts will continue in store for some time, these levers may, at the expense of the fabric, be removed so that the surfaces may be packed together in a much smaller space, but this practice cannot be recommended where a quick erection of an aircraft may be called for. The tail planes and fins are usually free from such encumbrances and afford better facilities for the complete storage. No particular arrangement need be formulated, but it is preferable that the parts should be placed resting on their edges. With tail planes, which are adjustable in flight, certain parts of mechanism are integral with the structure, and the metal of these parts must be adequately protected during storage. The same thing applies to all the metal fittings, such as the levers previously referred to, and the treatment previously outlined for the metal parts of fuselages may be used in these cases. The tail planes of the larger types of aircraft may, on account of their size, be accommodated in racks similar to those used for the main planes of smaller aircraft.

Undercarriages and Chassis.

In a large number of cases the undercarriage or chassis remains attached to the fuselage to act as a support for it, but where this is not done, the component, usually being a non-rigid structure by itself, may be dismantled into its main parts. The undercarriage for an aeroplane may be sub-divided into the supporting struts and axle with, of course, the wheels removed. In this way it may be stored in a compact manner.

The simpler types of undercarriages consist of two sets of "V" struts connected to the axle through shock absorber elastic, and when this structure is dismantled the side struts may be packed separately with their respective fairings, and the axle with its fairings placed with these struts. The majority of undercarriages are constructed principally of steel, wood only being incorporated in so far as it is required for purposes of fairing. The requirements of storage of steel parts must therefore be met for the exposed metal portions, but the fairing gives partial protection to those parts which it covers. Particular attention should be given to mechanical shock absorbers such as is used in the Oleo type of landing gear. In these cases the simpler "V" construction is substituted by a more complicated mechanical contrivance, the mechanism of which calls for treatment. The guides for the shock absorbing springs must be carefully cleaned, together with the springs themselves, and all the working parts of the unit well oiled and finally coated with anti-rust preparation. In the matter of wheels and tyres these may be regarded as interchangeable parts to the extent that the provisions previously advocated to maintain the association of the part of an aircraft need not be rigidly carried out. All wheels of one size may be grouped together and stored, preferably on vertical spindles, or alternatively on horizontal spindles, with the tyres clear of the ground. The normal air pressure in the tyre of about 50lb. per square inch should be released, in this way avoiding fatigue to the rubber by relieving the tyre of surface tension. Whether tyres are removed from the wheels will depend a good deal upon the likely demand for the wheels. If, however, the wheels are to be stored for a considerable time, it is better to remove the tyres, as any rusting round the rim of the wheel where the tyre is in contact will cause depreciation of the rubber. With the tyres removed the fabric fairing covers on the wheels may also be taken off, and the spokes and hub cleaned and greased; particular care should be given to the internal portion of the hub to prevent the rusting.

After shock absorber elastic has been in use for some time it is questionable whether this material can again be utilised with efficiency. To render this a

possibility, however, it should be coiled and stored away under similar conditions as for tyres, that is in a place where the temperature is maintained fairly even, and where it will be quite free from oil.

If a complete undercarriage is likely to be required quickly from store, it may, after being removed from the aircraft, be kept in its complete condition by constructing a light framework which will anchor together the tops of the struts, and so complete the rigidity of the framework in the same way as when it is on the aircraft. In this way it will not be so convenient a component to store, but it is easily rendered available for use by removing the retaining framework from the tops of the struts, when it is ready to go straight on to the aircraft. It is hardly necessary to add that the bracing wires will, in most cases, have to be disconnected, and where the undercarriage is stored in parts, the bracing wires will be dealt with separately, as described later.

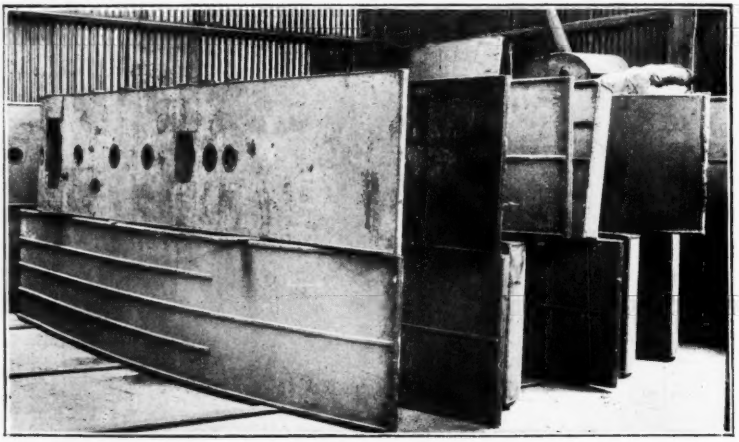

FIG. 23.—*Seaplane Floats in Store showing inspection covers removed.*

Considering the corresponding unit, as used on a seaplane, which for distinction is usually called the chassis, the make up of this component is constructively similar to an undercarriage in that it is a braced structure attached one end to the aircraft and having floats at its other end. Taking this component as a whole, the chief differences of treatment as compared with an undercarriage will be due to the effects of sea water, and to the frailty of the floats.

When the chassis is dismantled, the struts and bracing wires may be arranged similarly to those of an undercarriage, but the floats call for special comment. In storing these parts they can be arranged one above the other, resting either on their sides or on their bulkheads; for convenience in storing the former is preferable, as it gives a flat surface on which the float can rest, and on which battens may be placed for the support of the upper floats. In either case a space should be left all round each float for the free circulation of air, and the distance apart of each pile of floats should be at least one foot. During the time that floats are in store all the inspection covers should be opened up to give free access of air to the interior. The floats should be cleaned down before being placed in position in the storage shed, and all surplus water and dirt removed. Where three-ply construction is used, water must not be placed in the floats as it affects the glueing of

laminations and may cause buckling. The supports for these parts may conveniently be 3in. by 3in. quartering, which is laid in the first instance directly on the floor. The first set of floats rests on these supports, then further similar supports are laid along the top of these floats and a second tier placed over the first; it is not advisable to place more than two floats one above the other. Floats stored in this manner are shown in Fig. 23, in which they are arranged resting upon their sides and two deep upon the floor of the shed. All the precautions necessary for the satisfactory storage of thin timber and glued joints should be observed, the conditions of temperature and humidity of air being the chief factors.

Wing Tip and Tail Floats.

These floats are of lighter construction than main floats, and therefore fall to be dealt with by similar treatment. They should not be allowed to rest upon the floor, but may be either suspended or laid on quartering as detailed for main floats. In some instances it will be found convenient to accommodate them over the main plane racks with the control surfaces of the aircraft. In most cases strut bracing is attached to these floats, but its removal is not absolutely necessary owing to the small size of the unit. Care should be taken to see that the struts of one float are not placed so that they may penetrate the adjacent float, the fabric side coverings sometimes used being very easily damaged.

Bracing Wires and Cables.

Most of the external bracing of aircraft is now in the form of streamline wires, but cables are also used for such purposes as the bracing of the chassis of a seaplane. When an aircraft is dismantled for storage these bracing wires are detached and have, of course, to be stored in common with the rest of the aircraft.

For ease of subsequent erection of the aircraft it is essential to know to which part of the machine a particular wire or cable belongs, as in some cases the lengths may differ only very slightly and trouble will occur by trying to fit a wire of slightly incorrect length. The labelling of these parts, therefore, should be carefully done, as the location of a particular wire is sometimes not so obvious as that of a component such as a main plane. The system of identification of wires by brass tabs may conveniently be used to supplement the collective labelling. In cases of streamline wires, their shape enables them to bend easily in one direction, but undue bending may produce a permanent set which it is difficult to remove without injuring the wire. For this reason, when the wires are bunched up together, it is not sufficient to support them in a few places, but they should be laid on planking extending throughout their entire length. Each wire should, before storage, be treated by cleaning down and coating with a suitable anti-rust preparation, which should be applied thinly and evenly over the whole wire, and each wire be allowed to remain separate until a hard coating has been formed. When all the wires which it is required to group together have been so treated they may be bunched up, tied, and placed in store. It has been found that the surface developed by certain anti-rust compositions eventually becomes brittle, and the composition is liable to flake off, so that once a bunch of wires have been stored they should not be disturbed except for purposes of inspection and re-coating. Other protective means have from time to time been devised, and later it is possible that galvanising or sherardising may be employed.

Flexible steel cables have need for the same protection from corrosion as streamline wires, but as they are not so liable to take permanent set by moderate distortion there is no need to support them throughout their entire length. In

the cases of the smaller cables, however, there is a tendency to kink if they are badly coiled, and once a cable has developed a kink its efficiency is practically destroyed. In the process of storing these cables the opportunity should be taken to see that there are no frayed parts and that splices are in good condition.

Engines.

In dealing with the storage of engines as separate units, it is not proposed to enter into the detail matters of dismantling and overhaul, even though such operations may, in general, be desirable. The engines will be considered as units calling for special attention to the precautions for storing metal parts; only the mechanical parts will be dealt with and such accessories as oil and fuel tanks with their pipe systems will be omitted.

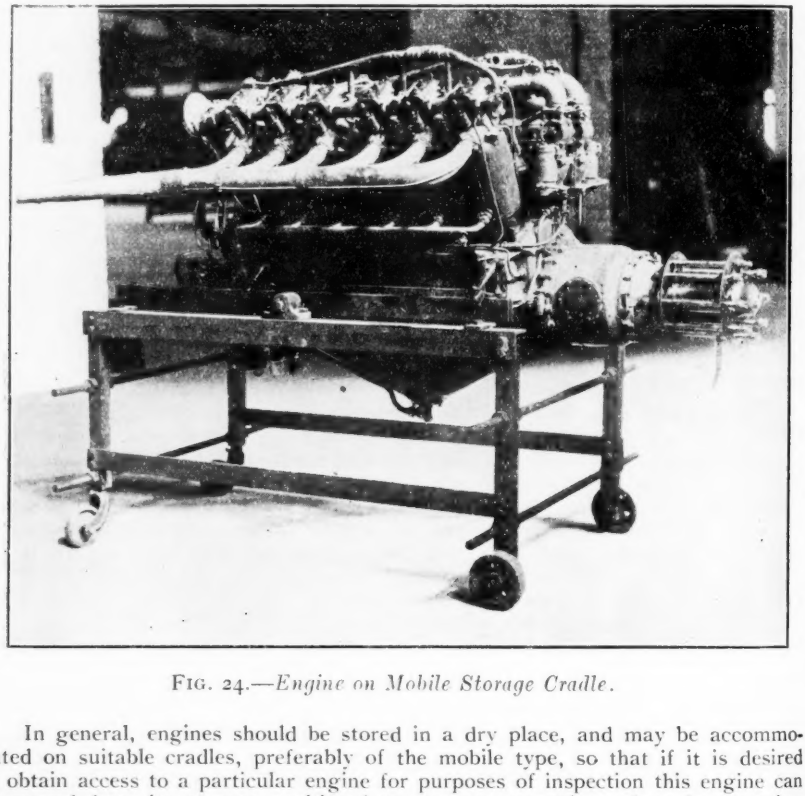

FIG. 24.—*Engine on Mobile Storage Cradle.*

In general, engines should be stored in a dry place, and may be accommodated on suitable cradles, preferably of the mobile type, so that if it is desired to obtain access to a particular engine for purposes of inspection this engine can be moved from its storage position into a more convenient place for carrying out the work. Each type of engine will necessarily call for a modification in the design of storage stand, but by constructing stands of sufficient width and length to accommodate the larger engines, they may also be used for the smaller types. A typical engine may be taken as the Rolls-Royce Eagle VIII., and in Fig. 24 an engine of this type is shown resting on a mobile cradle; the cradle in this instance being of steel construction, but a wooden cradle would serve the purpose equally well. It is essential that the engine be supported throughout its length as local loading causes stressing of the crankcase. The engine will normally

come into store as taken from the aircraft, and will contain some oil and possibly some water in its cylinder jackets. This oil and water must be removed from the engine, the removal of castor oil being very important on account of the property of this oil in absorbing water, and so causing corrosion of the metal parts with which it is in contact. It is next advisable to check over the external parts of the engine to see that they are all in position, after which the outside of the engine should be cleaned down and coated with an anti-rust preparation. It is an advantage to remove the carburettors and to clean these parts separately, afterwards replacing them on the engine. The plugs and magnetos may also be removed and stored as instruments, the holes of the former being closed by wooden pegs and those of the latter covered with fabric. Where the engine has been disconnected from its service system, the open pipes or unions must be closed to prevent the entry of dirt. For this purpose fabric covers can be cut out and tied in position over the various openings.

In the cases of rotary and radial engines the tappet rods should be disconnected and secured to the engine.

Before putting the engine away a small quantity of high grade thin oil should be poured into each cylinder, and squirted into the interior of the engine through the breathers, or—in the case of rotary engines—the crankshaft, and also into the gears where such are fitted. By turning the engine a few times, this new oil can be sufficiently distributed to form a film over the interior of the engine.

When the engine is located in a desired position in the storage shed it can be completely covered by fabric tied in position, but in attaching the fabric cover it must be remembered that periodically the engines are turned, and the attachment of a cover to the propeller boss and other moving parts should be arranged accordingly.

All loose external parts which belong to the engine should be removed, separately packed, and placed with the engine.

Airscrews.

Most existing airscrews are of wooden construction. They are sometimes fitted with metal tips or a metal sheath extending partly up the blade, and in a few instances they are of all-metal construction. The storage, however, will concern chiefly the wooden variety. The design and construction of the average airscrew makes it inherently liable to change of shape, and to trouble with its glued joints. Once joints have given way there is no remedy, and the airscrew has to be written off as unserviceable. The prime factor, therefore, in the conditions of storage of these parts is the temperature and humidity of the air, but further than this, as glue is an uncertain compound in its behaviour, it is necessary to have free movement of the airscrew when stored in a vertical position, and to overcome the vagaries of the glued joints and timber in laminated form, the airscrew has periodically to be turned.

In Figs. 25 and 26 are shown two methods of storage—in the first case for a four-bladed airscrew, and in the second, for a two-bladed airscrew. In the former, the airscrew is mounted vertically on a peg against the wall, and may occupy any convenient space in the storage shed, provided that it is not placed immediately over a radiator or in the vicinity of air currents of changing temperatures. As the wall of the building is liable to be coated with a deposit of dew under suitable atmospheric conditions, it is essential that the airscrew must have two or three inches clearance, and this may be ensured by placing short battens between the boss of the airscrew and the wall.

In the other method the disadvantages of placing the airscrews against a wall are overcome by having them on a rack. This rack is of simple design, and

constructed of substantial timberings with suitable pins projecting through its upper rail to carry the airscrews. Each pin is capable of accommodating two airscrews on each side of the rack. In this position the airscrews cannot be rotated as required, but similar effect may be obtained by removing a particular airscrew, turning it end for end, and replacing it on the rack.

It is a point to note that a rack of this description containing airscrews should not be placed where it will be exposed to the wind if the shed door be opened, as the effect of this may be to rotate the airscrews with sufficient violence to cause one airscrew blade to damage the edge of the next one.

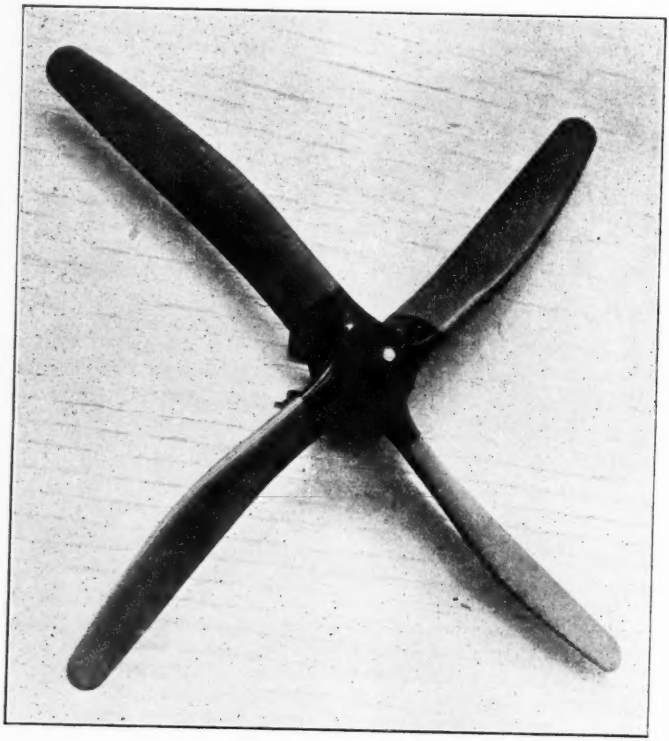

FIG. 25.—*Airscrew stored on Wall Peg.*

Another method which may be adopted is to place the airscrews in their packing cases, where such cases are available, and to stack the cases flat one above the other. Airscrews which are already packed may be accommodated in this way and need not be removed from their cases for storage by the previous method.

When airscrews are brought into store after being in flight they should be wiped down and any defects in the varnish made good before they are placed in store. In a similar way the fabric or metal sheaths, where such are used, should be inspected and any damaged places repaired.

In all cases the metal boss is removed from the airscrew prior to storage and either goes with the engine or is stored separately.

Instruments and Accessories.

The parts falling into this category are chiefly air speed indicators, revolution indicators, thermometers, compasses, pressure gauges and the like, added to which may be some of the intimate parts of engines such as magnetos. It should be borne in mind that these parts are costly, so that care must be taken to prevent losses while in store. At the same time it is necessary to guard against damage by seeing that they are carefully handled.

The fitting of these instruments usually does not call for so much detail as the constructional features of the aircraft, so that the same degree of association of these parts is not so necessary as say for main planes and tail planes, although for compasses and magnetos which have been set with respect to a particular aircraft or engine it is an advantage to have their exact location designated. It is a convenience, also, to have each instrument labelled with the designation of the aircraft into which it is normally fitted, but this information is of use primarily as a check upon the number of instruments, and apart from the exceptions given above it is not intended that the instruments should necessarily be replaced in the same aircraft. Having regard, therefore, to the above conditions it will be appreciated that a detailed clerical record is required for the successful storage of instruments, and these records should show the identification numbers of each instrument and particulars as to location in the store, together with identifying particulars of the aircraft from which they have been removed. These parts do not call for any special rack for their accommodation and they may be placed in bins, preferably of sheet steel.

It is sometimes recommended that instruments be tested before being placed in store, but in any case it is not expedient to place an instrument in use immediately after it has been stored for some time, without testing it prior to fitting. The components of some instruments are very susceptible to changes of temperature, and those which contain the rubber parts may, of course, depreciate through perishing of the rubber. It is advisable, therefore, that the building in which instruments are to be stored should be capable of being maintained at a constant temperature, and where possible, at a constant humidity. This purpose is best served by choosing a small building as an instrument store in which the atmospheric conditions may more easily be controlled.

Instruments containing mechanical mechanism should be protected internally from corrosion by the judicious injection of thin high grade oil.

Revolution Indicators.—Revolution indicators of the centrifugal type should have their mechanism covered with thin oil before being placed in store. The electric type of indicator must not be oiled and should be placed in a damp-proof compartment. It is an advantage to cover the open end of the connection for the flexible cable to prevent moisture from entering and damaging the interior of the instrument.

Both these types of indicators are operated by a flexible drive which consists of a rotating core within a flexible sheath. The outer sheath should be cleaned down and greased, while the flexible shaft should be removed and be liberally coated with grease before being replaced within the sheath.

Transmitting Radiator Thermometers.—The most important part of these instruments is the pipe connection between the indicator and the thermometer bulb. The whole system is hermetically sealed and when handling the instrument for storage purposes great care is needed to ensure that the pipe line does not become cracked through being faultily coiled, and that any joint in the system is not opened; the pipe line is fairly flexible material, but undue advantage must not be taken of this property to effect its storage in a very small space. The operating liquid is usually a volatile compound and easily affected by changes of temperature, and so as not to subject the indicator to continual loading, the place in

which these instruments are stored should have an even and not too high a temperature.

Air Speed Indicators.—These instruments depend for their operation on the functions of a hermetically sealed chamber, and the ends of the leading-in pipes should be capped off. Accompanying an air speed indicator will be a pressure head, and as the small holes in the static side must be kept clear, the storage bins or racks should be wiped out to remove dirt and dust before these instruments are placed in position. It is also necessary to avoid burring the edge of the pitôt tube, which in effect will alter the coefficient of the pressure head and the calibration of the indicator.

Compasses.—Compasses, with the card locked, should not be stored in the vicinity of a strong magnetic field. The instruments should be laid horizontally and after the compass has been placed in position the card should, where possible, firstly be freed and then locked when it has settled down. The same method of storage should be adopted for both liquid and dry types of compasses. As mentioned previously, for re-setting purposes, it is advantageous to indicate to which aircraft each particular compass belongs and its exact location in the aircraft.

Magnetos.—After removal from the engine each magneto should be cleaned down and oiled, avoiding any excess of oil and ensuring that no oil enters the electrical system; it should then be tested and if satisfactory be placed in store. Differing slightly from the principles of storage for the former instruments, these are arranged one only in each compartment of the rack. This scheme has been found a convenience for detecting missing stores.

A typical layout for instruments of the kind previously described is given in Fig. 27, in which is shown a steel rack with compartments for accommodating the various types of instruments. No attempt is made to vary the size of the compartments for the varying sizes of instruments, and a standard design of store rack is used. A number of modifications of this design are possible without detracting from its value, and that given in Fig. 27 is intended to represent only one type of storage rack which can be used.

Having dealt now with the more important instruments and accessories it remains to be said that the same principles should be followed when dealing with instruments other than those mentioned.

The instrument stores will also be found a convenient place to accommodate other small parts of aircraft, not themselves being instruments, such as bolts, nuts, pins and the like.

The instrument store, in common with the storage sheds for aircraft, should give accessibility to all the parts and be equipped with a system of fire extinguishers.

INSPECTIONS.

After aircraft or aircraft parts have been placed in store it is not sufficient that they be supported in the various ways described and then allowed to remain in these positions for a prolonged period. As has been stated, many of the materials of construction are liable, under varying atmospheric conditions, to deterioration, with the consequent loss of efficiency of the part in which these materials have been used. The corrosion of steel and the warping of timber are obvious examples of what will occur. During storage steps are taken to protect the parts as far as possible from these effects, both by excluding air from the material by the use of a grease film and by maintaining the atmospheric conditions within the storage sheds fairly constant, but even with these precautions there will always be a certain amount of unforeseen corrosion and deterioration, which if allowed to continue will eventually spread to such an extent as to render the material useless. To overcome these diffi-

culties, therefore, a system of inspections has to be formulated and its operation should detect the troubles in their early stages and give an opportunity for rectification. These inspections should take the form of ascertaining in detail the state of any stored part at periods of varying frequency depending upon the part concerned and the conditions under which it is stored. It is not intended that the inspections outlined should be rigidly adhered to, but their purpose is to show roughly the frequency and the detail of the inspections which are recommended. For consistency with previous descriptions, the inspections for complete aircraft will first be considered, to be followed up by those required on the various components.

Complete Aircraft.

The inspection of complete aircraft should be carried out once a month, the order for this work being as follows:—

The supports for the aircraft should be checked for being up to their work and any packing pieces which may have worked loose should be tightened up so that they carry their share of the load; in the case of wing supports when the wings are folded, these should be checked to prevent sagging of the wings. The complete aircraft should be wiped over for the removal of any dirt, and where old types of storage sheds are being used it should be ascertained whether water is leaking through the roof on to any part of the aircraft, and if so, a remedy applied. The covers should be removed from the engines and the engines turned through a few revolutions; if an engine is unduly sticky, thin oil should be injected before turning and any surplus oil run off from the sump. The undercarriage wheels should be clear of the ground and any settling down should be rectified by adding packing wedges under the undercarriage. A complete examination of the main plane fabric, struts, and bracing wires should be made, and if there are signs that the wing is suffering from internal defects, the fabric should be opened up round the doubtful part for inspection; it must afterwards be made good when the inspection is completed. In a similar way the structure of the fuselage should be examined, and in the types of aircraft where longerons of McGruer construction are used, these should be checked for faulty joints and to see that sagging is not occurring in any part of their length. The instruments such as are left in the aircraft during storage should be checked over, both for completeness and efficiency. Where the available space exists and an aircraft is stored with its main planes folded, the machine should be spread in order to check the alignment of the wing pins and locking bolts, after which it may be returned to its folded position. The coating of anti-rust preparation on metal parts should be cleaned off, the part rubbed down, and a fresh application of the composition made; this operation should extend to the metal struts of the undercarriage, the engines and all the external bracing wires. The tyres of the wheels should be examined for signs of perishing of the rubber, and it is an advantage to remove each wheel, clean the axle, re-coat it with anti-rust grease and replace the wheel.

In the case of seaplanes the same operations should be applied to the superstructure, but a special treatment is necessary for the floats or hulls, as outlined later. In inspecting these parts any opening of joints or other signs of the loss of watertightness should be detected. If hulls and floats have been coated with paint or other water-resisting material, this protecting surface should be intact, and if cracks have developed a fresh coating should be applied. Where arrangements have been made to maintain watertightness by placing water inside the hull, this water should at periods of inspections be removed to prevent stagnation and fresh water placed in the hull. During the summer months this operation will probably be required at every inspection, but during the winter it may be carried out at every second inspection. The internal metal fittings of the hull should be examined for signs of corrosion and the early stages of any corrosion removed and further developments checked by a fresh coating of anti-rust com-

position. For aluminium fittings a protective varnish consisting of one part of velure varnish and two parts turpentine may be applied.

In the foregoing manner the detail of the complete aircraft should be dealt with, and if these inspections be properly carried out there will be little opportunity for deterioration of the aircraft.

When complete aircraft have been in store for a considerable time, such as periods of one year or more, even though they are subjected to the monthly inspections as previously outlined, a further safeguard is recommended before any particular machine is taken into the air. This latter check on the safety of the aircraft is carried out by choosing a sample machine and subjecting it to strength tests, either up to the factor of safety of the design, or even to destruction. If the aircraft stands up satisfactorily to this test it may be reasonably assumed that the other aircraft are in a fit condition to be taken into the air.

Fuselages.

The inspection of fuselages should take place once every month and should be of such a character as will reveal any tendency to permanent deformation of the structure, either through inadequate supporting or variation in atmospheric conditions. The alignment of the structure should be checked over, which can usually be done by sighting along the longerons, and if any part is found to be sagging it should be further supported to reduce this tendency. In the case of wooden fuselages the longerons and struts should be examined for deterioration of the timber, and if any strut shows signs of weakness, steps should be taken to have a replacement fitted. The metal fittings and bracing wires should be gone over, and after being carefully cleaned down, should be re-coated with anti-rust composition. After this inspection the whole fuselage, when covered, should be cleaned down and any weak places in the fabric made good. Where the fuselages are stored complete with their fabric covers, the internal examination should be carried out by removing the fabric and if necessary cutting it away from the parts required to be inspected—it is easier to replace fabric on a fuselage than to rebuild the structure.

The above remarks are applicable to wooden fuselages, but those of metal construction should receive inspections with the same frequency, during which examination of the joints should be the central feature. If these joints are pinned and brazed there is a tendency for minute defects to develop during storage and these will show themselves as fine cracks in the brazing. For these reasons the examination will necessarily have to be intensive and need only be applied to sample fuselages. The protective composition which is cleaned off prior to examination will be substituted by a fresh coating when the examination has been completed.

Hulls.

The frequency of inspection for seaplane hulls should be of the same order as for fuselages, and for this inspection the chief point to consider is the watertight property of the structure. Resting as it does in a well fitting cradle and in view of the shape of the structure, it is unlikely that any distortion will occur. When the hull is stored with water inside, the tightness of the joints may be construed from an examination for traces of water either on the exterior of the hull or on the cradle; the water must then be emptied out before complete inspection of the hull. The inspection will then take the form of a detailed examination of the joints of the structure, both internally and externally and above and below the water line, after which the metal fittings may be examined and any corrosion removed—or if this be very serious the entire fitting removed—and a fresh application of protective composition made. If this inspection reveals a tendency for leakage, the hull structure may be coated with white lead paint,

which should be left untouched until it is quite dry. An external application only may be used first, and then if necessary on subsequent inspections, an internal application also made. If a renewal is required of the water in the interior of the hull, fresh water only should be used. The hull should be wiped over and fresh varnish applied where necessary. If water is not placed inside the hull the same object may be achieved by placing damp matting along the fins, this matting being damped occasionally to transmit the water to the joints of the hull structure. Under these conditions the matting will, of course, be removed for inspection and afterwards replaced in position. If the hull cradle does not allow a detailed inspection of the keel and bottom of the hull structure, the complete hull should be lifted from the cradle for this purpose, and either supported on temporary trestles while the cradle is removed, or suspended from an overhead gantry where such is available.

Main Planes.

The inspection of main planes should be carried out once every two months. Under conditions of rack storage a detailed examination of an individual plane is not possible with the plane in position in the rack. Each plane should therefore be removed in turn and placed where it can be inspected in detail. The whole plane, prior to inspection, should be cleaned, and in this way the defects of the fabric may be revealed. The metal fittings should have the treatment previously prescribed for such parts. Internal defects of the plane can best be located by feeling round the ribs outside the fabric, and if a particular place is thought to be weak, the fabric at that spot should be removed for detailed examination. In any case it is advisable to remove the fabric of one or two sample planes at the important points, such as the compression ribs, in order to enable a detailed examination of these parts of the structure; if the planes thus inspected are found to be satisfactory it will be a good guide as to the conditions of the other planes in the same store. When planes are stored on their leading edges and the conditions render it unavoidable that they must back on to a blank wall, there arises the possibility of damage owing to the attacks of vermin, so that when the planes are removed from racks of this nature their ends, which have been liable to this damage, should be inspected.

Inspections of metal planes need not be carried out with such frequency as those of the wooden variety, and once every three months should be sufficient for these types.

Control Surfaces.

A monthly inspection of these parts should be carried out, and in course of this examination the metal parts, being chiefly hinges and important fittings, require the most attention. Many of these components are of metal construction, fabric covered, so that apart from damage to the fabric there is little liability of depreciation of the structure. All these parts should, of course, be cleaned before inspection and afterwards have their exposed metal portions protected with grease.

Undercarriages and Chassis.

A monthly inspection of these parts should be sufficient to maintain their efficiency. With undercarriages stored in separate pieces, each part can receive separate inspection. In this category will be the undercarriage struts and axles with their fairings, and the inspection should determine that the fairings are properly attached to the struts and that the metal of the struts is receiving adequate protection. If the binding tape which is served round the fairing and the strut is weak, it will allow the fairing to twist round the strut, and in cases where this trouble has developed fresh binding tape should be used.

The wheels should be inspected for defects of the tyres. It is unlikely that the metal structure of the wheel will develop serious defects during storage, but where wheels are stored complete with tyres the possibility of the rim rusting where it is in contact with the tyre should not be forgotten, and a sample tyre here and there should be removed from the rim to investigate these conditions.

Shock absorber elastic calls for no special comment apart from the inspection of the state of the rubber, bearing in mind that this material perishes although not in use. Mechanical shock absorbers, such as are found on the Handley Page undercarriage and Oleo gear, should be dismantled for inspection, the parts cleaned, and if satisfactory the gear may be re-assembled with a fresh coating of grease.

The inspection of chassis for seaplanes is needed with about the same frequency as that of undercarriages, but in this case the possibilities of corrosion of the metal parts are increased by the effects of sea water. The examination should therefore be applied in detail to the struts and metal fittings and the same treatment accorded as for the protection of other metal parts of the aircraft. The serviceability of the floats should be checked with particular reference to their watertight properties and, if necessary, a fresh coat of water-resisting paint should be applied to the exterior after it has previously been cleaned. A few sample floats should be selected from the number in store and placed in water to see whether they leak. In this way the watertightness of the other floats may be estimated.

Wing Tip and Tail Floats.

A monthly inspection of these parts is recommended, and in course of this work the metal struts and other fittings should be treated and the watertight properties of the floats investigated. In cases of floats with fabric sides, the condition of this fabric should be examined with a view to renewal if any damage has occurred.

Bracing Wires and Cables.

With streamline bracing wires tied up in bundles, there is a tendency for certain protective compositions to flake off by contact of one wire with another, and further, if the wires have been bunched up before the composition is quite dry, one wire will stick to another, and in doing so, will leave a line of contact down each wire. When this has occurred and the wires are separated, it will be found that rusting has probably commenced where the wires have been in contact. For inspection of these parts, therefore, the wires must be separated from each other and all traces of such corrosion removed. They can then be re-stored as detailed previously.

Engines.

Complete engines or engine parts should be inspected every month. After having removed all the grease from the exterior parts, the engine should be turned through a few revolutions, and at the same time oil drained from the interior. A further supply of high-grade mineral oil, not castor oil, should be squirted into the cylinders and other working parts, such as gears and the like, and the turning continued to ensure that this fresh oil reaches all the interior parts of the engine. All traces of rust on the valve springs or other parts of the engine should carefully be removed before the fresh grease coating is applied. It is important when cleaning down the engine or removing corrosion, that all the ports or openings which admit to the interior of the engine should be kept covered to prevent the material removed from gaining access to the interior of the engine. After inspection, all the covers should be replaced.

Airscrews.

The inspection of airscrews should be carried out every two weeks, and should consist of an examination for lamination faults or warping of the blades. When airscrews have been stored uncovered, either on pegs in the wall or on a rack, they may, if their location is inconvenient, be removed from their storage positions to obtain better access for a more detailed inspection. Prior to inspection the blades should be wiped over with a dry chamois leather to remove any moisture or dirt. Each joint between the laminations should be inspected throughout its length, and in cases where the blades are tipped with metal or

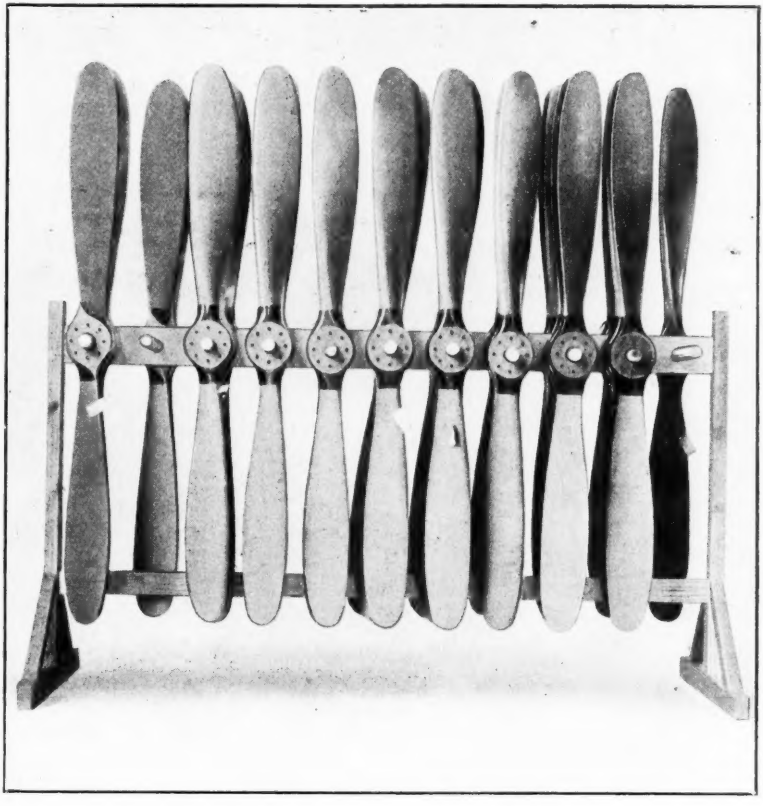

FIG. 26.—*Airscrews stored on Racks.*

fabric, these local coverings should be secure. In a few instances such fabric covers may, either in the whole or part, be removed to expose that part of the blade for inspection; after this new covers should be secured in position. The varnished surface of the blades should be intact, and if there are signs of the surface disintegrating, the parts affected should be cleaned off and a fresh application of varnish made.

When airscrews have been stored in their cases, they should, for purposes of inspection, be removed and afterwards replaced. In addition to these fortnightly inspections airscrews should be turned once a week, four-bladed air-

screws being turned through 90 deg. each time, and two-bladed airscrews through 180 deg. It is of course obvious that no such similar operation can be carried out when the airscrews are stored in their packing cases.

Instruments and Accessories.

With the type of instruments in general use, inspections should be carried out about once every two months. During these inspections it is not possible to examine in detail the internal parts of each instrument, but external defects should be noted. As a guide to the condition of the instruments in store, one or two

FIG. 27.—*Instruments in Storage Bins.*

samples of each type should be selected, and these subjected to suitable tests. The behaviour of these samples under test will give an idea of the condition of the remaining instruments. These remarks also apply to engine parts, such as magnetos and all other accessories whose functions depend upon the action of mechanism.

Raw Materials.

Where raw materials are stored, frequent inspections are not so essential, but a periodical examination can be carried out on such materials as wood, fabric, rubber and the like, as these materials are more liable to deteriorate by ageing. The best method of determining the condition of these materials is to take samples and subject them to appropriate tests.

REVIEW.

The War in the Air (Official History of the Air). By Sir Walter Raleigh. Oxford: Clarendon Press. 21s.

In reading a book published "by direction of the Historical Section of the Committee of Imperial Defence" one inevitably comes to consider the object of such official histories, what information they are intended to convey, and what class of reader they are designed to reach. In the case of the older services the answers would clearly appear to be that these publications are intended to provide documentary evidence of unimpeachable accuracy of the strategical and tactical dispositions of the rival forces at various periods, the reasons for those dispositions (where these are available or deducible) and their effects. The complete history then proceeds to draw lessons from this evidence; and the whole provides a valuable text book for the instruction of future generations who may have to apply the lessons, in the light of further experience and subject to such modifications as various changes may dictate. This book is to be judged from a different standpoint as an impartial account by a great literary stylist of the tribulations and achievements of some of those who had to wield a new weapon and fit it into the military machine. The decision to adopt this course may well have been correct in view of the difficulty of drawing any very definite instruction for the conduct of operations from the use of aircraft in the late war. Indeed, the tactics and strategy of the air, hardly even begun to be developed by November, 1918, are not much further to-day.

Sir Walter Raleigh, whose enthusiasm for his subject was no less notable than was his mastery of style, has provided the public with a most readable and in places enthralling narrative, often made to glow by descriptions from the mouths of the chief participants. This method, while indubitably infusing that life into the story which it was the author's desire to impart, has perhaps at times the defect of destroying the balance by giving undue prominence to certain incidents owing to the survival of the persons concerned. One regrets to say of a book produced under such auspices, that there appear to be inaccuracies here and there. It is, for example, somewhat surprising to be told that the Dunne aeroplane of pre-war days "took hints from the zannonia (*sic*) leaf," when in his paper before this Society, on January 29th, 1913, Mr. J. W. Dunne himself said,* "Violently opposed to the zanonia leaf type in most characteristics are the wing forms in . . . the division to which I have given my attention since 1904."

Or, again, in recording the early experiments with balloons in 1783 the Christian names of the two Montgolfier brothers are given as Joseph and Jacques, whereas the latter is referred to in all contemporary accounts as Etienne.

The lack of an index, which is presumably being reserved for a later volume, makes it difficult to be certain of omissions. There appears to be, however, no mention of the "Morning Post" Lebaudy or the Clément-Bayard airships, or of the patrol of Parseval No. 4 airship over the approaches to the Thames on the night of August 5-6, 1914, which antedated the first operations of the R.N.A.S. (August 8) and R.F.C. (August 19) recorded. Without the aid of an index it is difficult to be absolutely certain on these points, but a careful reading of the book has failed to reveal them. Altogether one is inclined to think that less informa-

* Aeronautical Journal, Vol. XVII., p. 86.

tion must have become available as to the early work of the R.N.A.S. than of the R.F.C., though the notes on the organisation of the latter in the chapter on "The Expansion of the Air Force" are surely open to criticism.

Reference has already been made to the literary character of the writing which of itself makes this book acceptable. No one else could have depicted half so well the romance of the eighteenth century balloonists or the early struggles of the aviation pioneers of a hundred years later, and when the author comes to deal with the first participations of the new arm in the war he pays a worthy and touching tribute to the matchless courage and devotion of the men who were called upon to found the traditions of the flying services. Sir Walter Raleigh's death when only at the outset of his task is a loss which will be for ever deplored and must inevitably change the character of the account in future volumes, since it will be hard for whoever succeeds him to breathe quite the same spirit of romance into the narrative.